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ABSTRACT

In 1964, Canyonlands was established as the 32nd U.S. national park, covering 400 square miles at the junction of the Green and Colorado Rivers in Utah. This booklet gives the early history of the area, a summary of the geologic history of the park, and a description of the high mesas, benchlands, and canyons. There are 81 illustrations including maps, charts, and photographs of the Canyonlands. Additional readings and selected references are included. (MA)

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The Geologic Story of Canyonlands National Park

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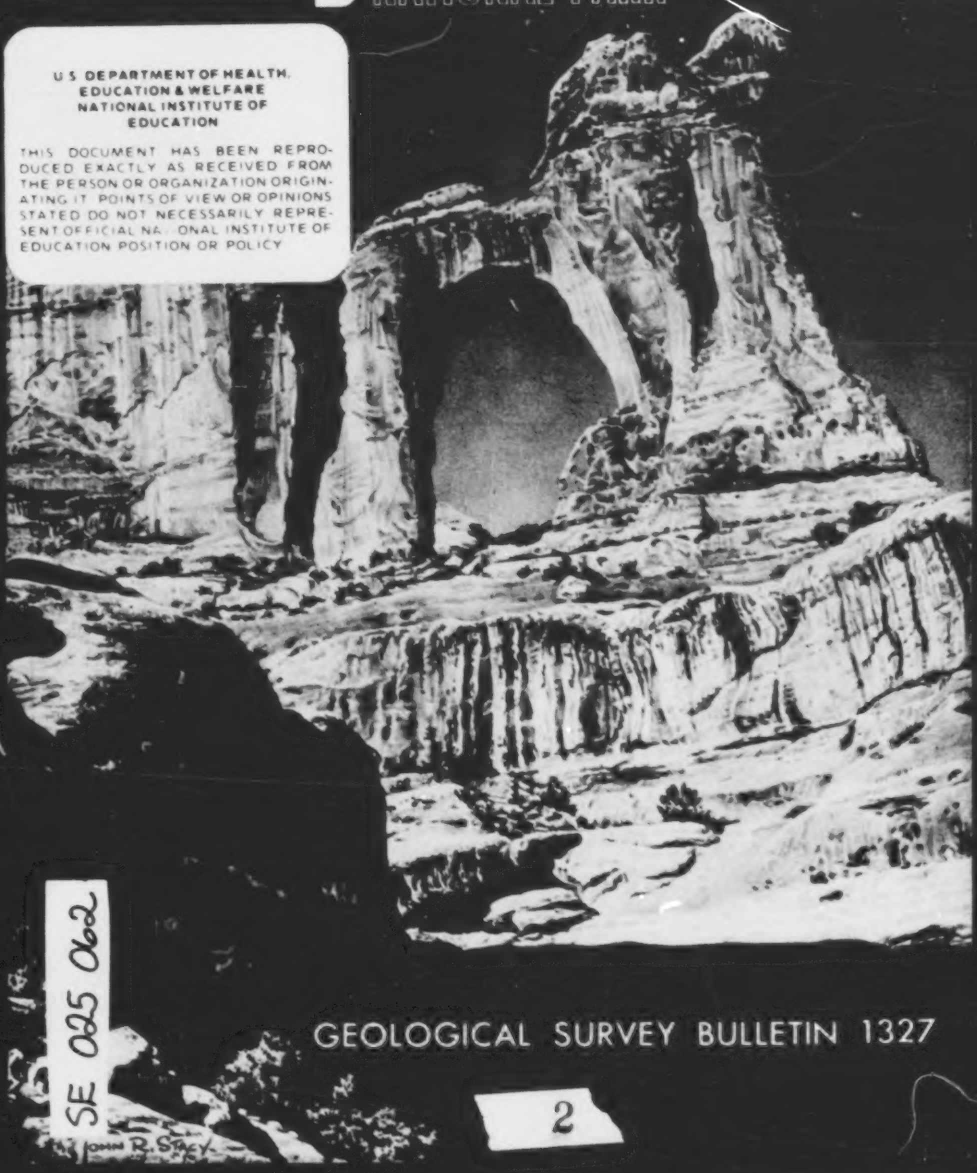

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GEOLOGICAL SURVEY BULLETIN 1327

LOOKING NORTH FROM EAST WALL OF DEVILS LANE, just south of the Silver Stairs. Needles are Cedar Mesa Sandstone. Junction Butte and Grand View Point lie across Colorado River in background.

The Geologic Story of Canyonlands National Park

By S. W. Lohman

Graphics by John R. Stacy

GEOLOGICAL SURVEY BULLETIN 1327

UNITED STATES DEPARTMENT OF THE INTERIOR

ROGERS C. B. MORTON, ***Secretary***

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A New Park is Born

On September 12, 1964, President Lyndon B. Johnson signed an act of Congress establishing Canyonlands as our thirty-second national park, the first addition to the park system since 1956.

The birth of Canyonlands National Park was not without labor pains. In the 1930's virtually all the vast canyon country between Moab, Utah, and Grand Canyon, Ariz., was studied for a projected Escalante National Park. But Escalante failed to get off the ground, even when a second attempt was made in the 1950's. Not until another proposal had been made and legislative compromises had been worked out did the park materialize, this time under a new name—Canyonlands. Among the many dignitaries who witnessed the signature on September 12 was one of the men most responsible for the park's creation, park superintendent Bates E. [illegible]son, who did the pioneer spade work in the field.

The newborn park covered 400 square miles[1] at the junction of the Green and Colorado Rivers in Utah. It included such magnificent features as Island in the Sky, The Needles, Upheaval Dome, and the two great stone formations, Angel Arch and Druid Arch. On November 16, 1971, President Richard M. Nixon signed an act of Congress enlarging the park by 125 square miles in four separate parcels of land, so the area now totals 525 square miles, all in southeastern Utah, as shown on the map (fig. 1). The northern boundary was extended to include parts of Taylor and Shafer Canyons. The addition at the southeast corner takes in the headwaters of Salt and Lavender Canyons and part of Davis Canyon. The largest addition, at the southwest corner, includes grotesquely carved areas bearing such colorful names as The Maze, Land of Standing Rocks, The Fins, The Doll House (fig. 36), and Ernies Country (named after Ernie Larson, an early-day sheepman). The fourth parcel lies about 8 miles west of the northwest corner and encompasses much of Horseshoe Canyon, whose walls are adorned by striking pictographs (fig. 2).

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[1] For the benefit of visitors from countries using the metric system, the following conversion factors may be helpful: 1 square mile = 2.590 square kilometers, 1 acre = 0.4047 hectare, 1 inch = 2.54 centimeters, 1 foot = 0.305 meter, 1 mile = 1.609 kilometers, 1 U.S. gallon = 0.00379 cubic meter.

At this writing (1973) the park is still in its infancy, with most of the planned developments and improvements awaiting time and money, but a good start has been made. In 1960 my family and I first traversed Island in the Sky to Grand View Point over a rough jeep trail; now it is reached with ease over a good graded road which eventually will be paved. A temporary trailer-housed entrance station near The Neck will be replaced by permanent headquarters for the Island in the Sky district after water is piped up from wells drilled near the mouth of Taylor Canyon.

In August 1965, when the Park was but 11 months old, we drove the family car over a two-track dirt "road" from Dugout Ranch to Cave Spring—temporary headquarters for the Needles district of the park, whose personnel were housed partly in trailers and partly in the cave. Now a modern paved highway, built by the State (Utah Highway 11) for 19 miles to Dugout Ranch and by San Juan County, the State of Utah, and the National Park Service for the next 18 miles, extends a total of 38 miles from U.S. Highway 163 to a new modern campground at Squaw Flat (fig. 39). The entrance station and housing for park personnel are now in trailers about 2 miles west of Cave Spring, but the trailers will be replaced by permanent structures. A shallow well near temporary headquarters supplies the only water available to the campground 1.5 miles to the west, but a new supply is to be developed for the campground and permanent headquarters. Groceries, gasoline, trailer hookups, and charter flights are available at Canyonlands Resort, just outside the eastern park boundary. The old cowboy line camp at Cave Spring has been restored so that visitors can see this phase of colorful Canyonlands history (fig. 6). Except for 2½ miles of partly graded road west from Squaw Flat, all travel to the west and south is by four-wheel-drive vehicle or on foot. In order to reach the confluence of the Green and Colorado Rivers, The Grabens, and Chesler and Virginia Parks, drivers must conquer formidable Elephant Hill, with its 40 percent grades and backup switchbacks. SOB Hill and the Silver Stairs also tax the skill and patience of jeepsters. Parts of this area will eventually be reached by graded roads, possibly by about 1977, but many hope that much of it will be kept accessible only by jeep or foot trails.

Bates Wilson, recently retired superintendent not only of Canyonlands National Park but also of nearby Arches National Park and of Natural Bridges National Monument about 80 miles to the south, is one of the few men in the park service who has guided a national park through all phases—location, promotion, establishment, and initial development. He retired in June 1972 to a ranch along the Colorado River north of Moab.

Unless credited to others, for which grateful acknowledgment is made, the color photographs were taken by me. Most of these were taken on 4- by 5-inch film in a tripod-mounted press camera using lenses of several focal lengths, but a few were taken on 35-millimeter film. Unless credited to others, the black and white photographs were kindly loaned from the Moab and Arches files of the National Park Service. The points from which most of the photographs were taken are shown in figure 19.

Major Powell's River Expeditions

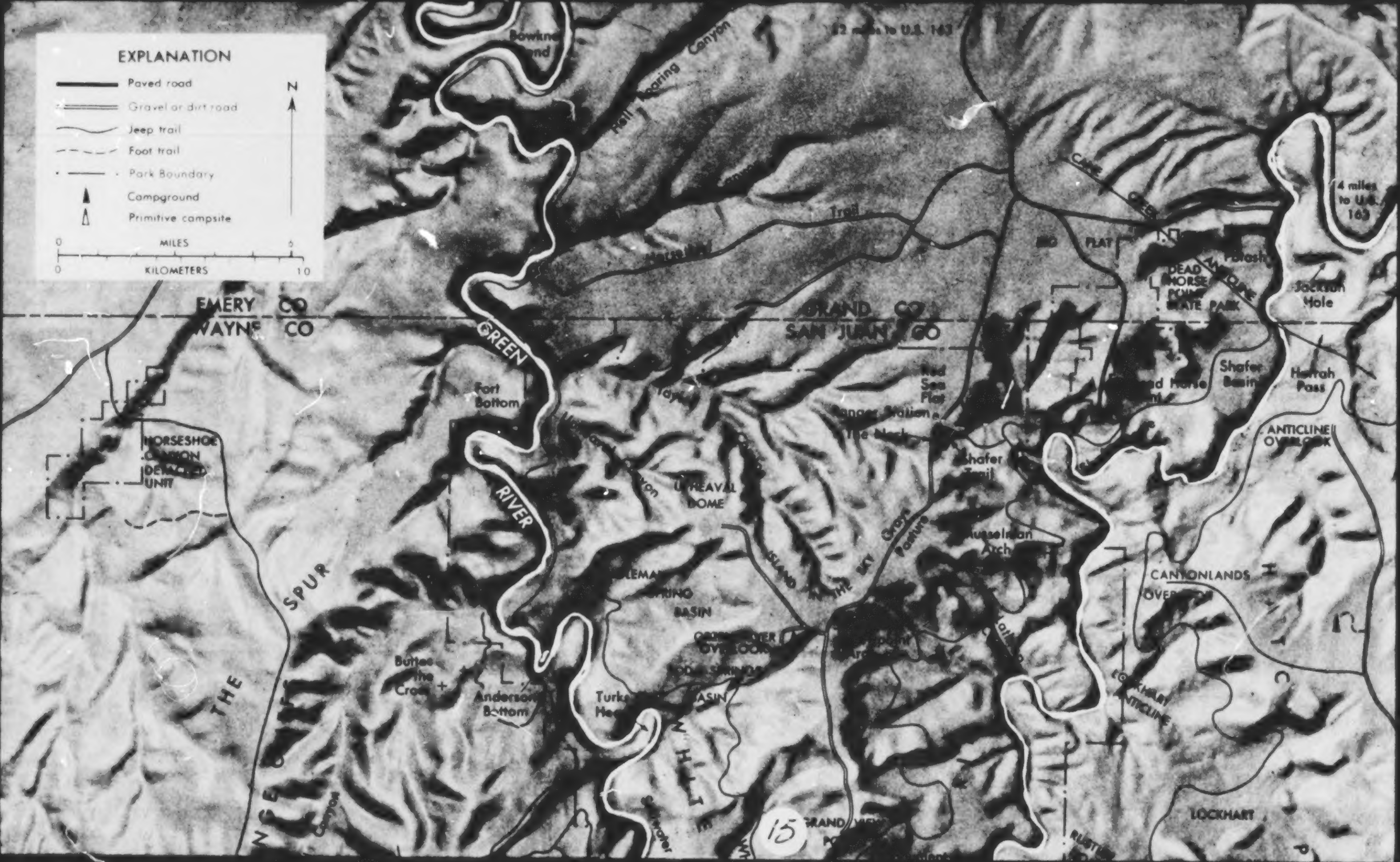
Although Major John Wesley Powell was not the first geologist to view the canyon lands, his two daring boat trips down the Green and Colorado Rivers in 1869 and 1871 made history by bringing to light the first descriptions of the geography and geology of what was then the largest remaining uncharted wilderness in the United States. Many landmarks along the canyons in the park were named by Powell and his men during those explorations. J. S. Newberry is thought to have been the first geologist to view the canyon lands—at least he seems to have been the first one whose observations were recorded (1861), but the more comprehensive findings of Powell (1875) were the ones that made history.

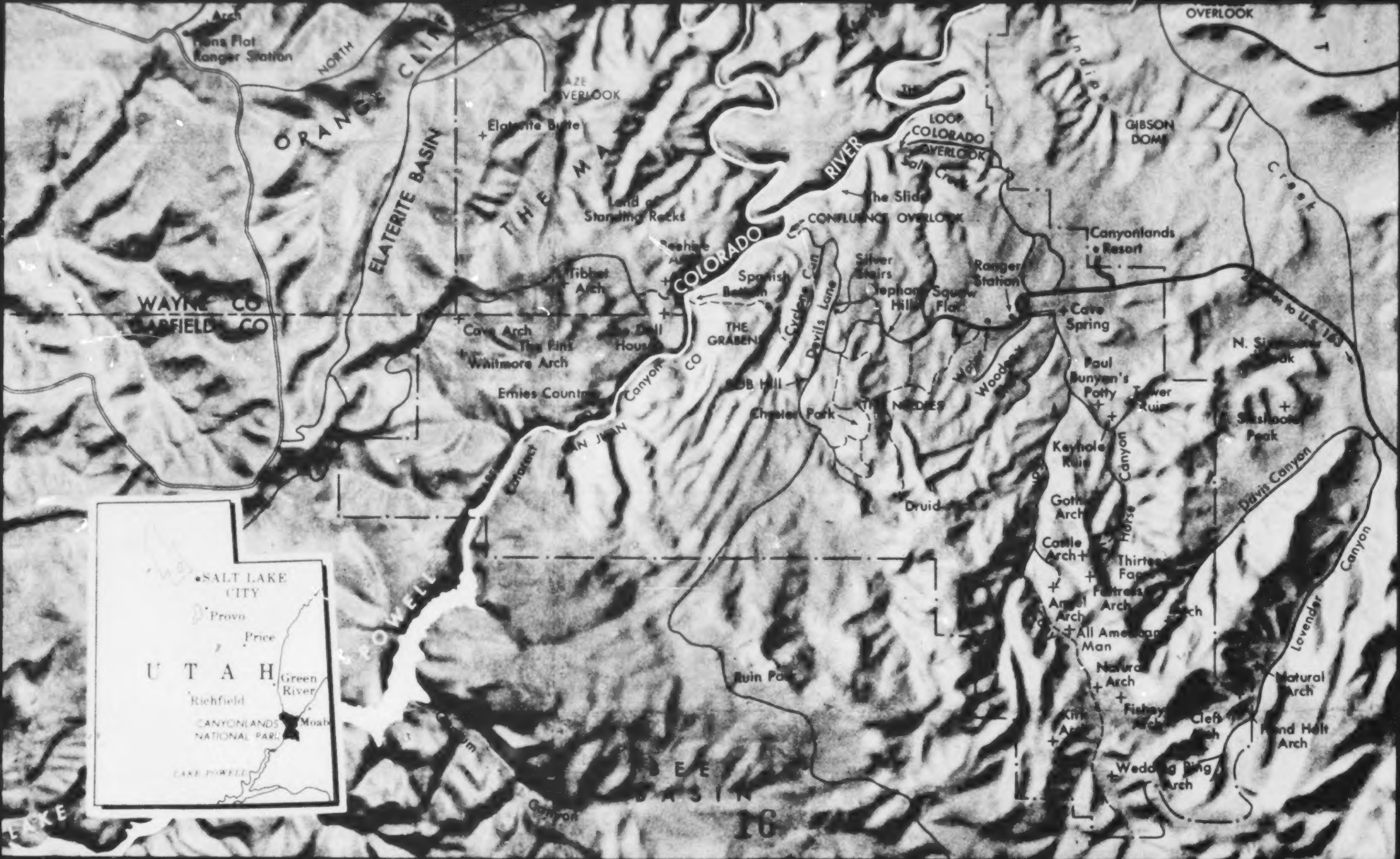
The 100th anniversary of Major Powell's pioneer exploration of the Green and Colorado Rivers was commemorated in 1969 by a national centennial sponsored jointly by the U.S. Department of the Interior, the Smithsonian Institution, the National Geographic Society, and many other organizations. This touched off many magazine and newspaper articles, several commemorative programs and dedications, and several publications of lasting interest. Noteworthy among the latter is U.S. Geological Survey Professional Paper 669 entitled "The Colorado River Region and John Wesley Powell." Of its four separate parts, two are of special interest to our Canyonlands story: part A, "John Wesley Powell: Pioneer Statesman of Federal Science," by Rabbitt (1969) and part C, "Geologic History of the Colorado River," by Hunt (1969). An interesting history of the National Park Service by Everhart (1972) was published as part of the national park centennial effort. The Powell Society, Ltd., of Denver, Colo., was founded mainly to publish four "River Runners' Guides to the Canyons of the Green and Colorado Rivers, with Emphasis on Geologic Features," covering five reaches of the two rivers from Flaming Gorge Dam, Utah, to

Grand Canyon, Ariz. One of these by Mutschler (1969) covers Labyrinth, Stillwater, and Cataract Canyons, all in Canyonlands National Park. Another guidebook by Baars and Molenaar (1971) covers the Colorado River from about Potash, Utah, to the confluence with the Green, and Cataract Canyon. It is difficult to realize that thousands of people annually now boat down the canyons Powell dared to explore without knowledge of the dangers that lay ahead.

During the summer of 1968 a U.S. Geological Survey expedition led by Eugene M. Shoemaker retraced the historic 1869 and 1871 river voyages of Major Powell, in order to reoccupy the camera stations of the 1871 voyage and rephotograph the same scenes nearly 100 years later. Remarkably enough, about 150 camera stations were recovered, many requiring considerable search, and official photographer Hal G. Stephens rephotographed the scenes taken with cumbersome wet-plate cameras nearly 100 years earlier by E. O. Beaman (above the site of Lees Ferry) and by J. K. Hillers (below the site). A report containing these remarkable sets of before and after photographs hopefully will be published eventually as a delayed part of the Powell centennial. A few pairs have been published by others (Baars and Molenaar, 1971, p. 90-99), and two pairs are shown herein as figures 62 and 67. As these photographs show, in most places the rocks and even the vegetation remain virtually unchanged after nearly a century, but a few other pairs not included herein show catastrophic changes resulting from local floods or rockfalls.

CANYONLANDS NATIONAL PARK, showing location in Utah, Lake Powell, Dead Horse ▷ Point State Park, boundaries, streams, roads, trails, landforms, and principal named features. There was insufficient room to show all named features; some not shown are related in text by distance and direction to named ones, and some additional names are given in figures 7, 51, and 59. Hans Flat Ranger Station near left border is in Glen Canyon National Recreation Area. The reader is referred to road maps issued by the State or by oil companies for the location of U.S. Highway 163 (shown as 160 on old maps) and other nearby roads and for the locations of the towns of Green River, Crescent Junction, Moab, La Sal Junction, and Monticello. Visitors also can obtain pamphlets at the entrance stations to the Needles and Island in the Sky districts of the park or at the National Park Service office in Moab; these contain up-to-date maps of the park and the latest available information on roads, trails, campsites, and picnic sites. (Fig. 1)


EXPLANATION
Paved road
Gravel or dirt road
Jeep trail
Foot trail
Park Boundary
Campground
Primitive campsite
N
MILES
0
6
KILOMETERS
0
10
Bowknot Bend
Hell Roaring Canyon
12 miles to U.S. 163
Trail
4 miles to U.S. 163
BIG FLAT
CANE CREEK ANTICLINE
DEAD HORSE POINT STATE PARK
Potash
Jackson Hole
EMERY CO
WAYNE CO
GRAND CO
SAN JUAN CO
GREEN RIVER
Fort Bottom
Taylor
Red Sea Flat
Ranger Station
The Neck
Dead Horse Point
Shafer Basin
Hurrah Pass
HORSESHOE CANYON DETACHED UNIT
Shafer Trail
UPHEAVAL DOME
ISLAND IN THE SKY
Grays Pasture
Musselman Arch
ANTICLINE OVERLOOK
CANYONLANDS OVERLOOK
SPRING BASIN
GREEN RIVER OVERLOOK
SODA SPRINGS BASIN
THE SPUR
Buttes of the Cross
Anderson Bottom
Turks Head
LOCKHART ANTICLINE
LOCKHART
GRAND VIEW POINT
HATCH
Canyon


Arch
Hans Flat
Ranger Station
NORTH
ORANGE CLIFFS
ELATERITE BASIN
MAZE
OVERLOOK
Elaterite Butte
THE MAZE
Land of
Standing Rocks
COLORADO
RIVER
LOOP
COLORADO
OVERLOOK
Salt Creek
The Slide
CONFLUENCE OVERLOOK
Beehive
Arch
Tibbet
Arch
Spanish
Bottom
Silver
Stairs
Elephant
Hill
Squaw
Flat
Ranger
Station
Canyonlands
Resort
GIBSON
DOME
Indian
Creek
OVERLOOK
Cave
Spring
Miles to U.S. 163
WAYNE CO
GARFIELD CO
Cave Arch
The Fins
Whitmore Arch
The Doll
House
THE
GRABEN
Cyclone Canyon
Devils Lane
SOB Hill
Ernies Country
Canyon
Chesler Park
THE NEEDLES
Woodenshoe
Paul
Bunyan's
Potty
Tower
Ruin
N. Six-shooter
Peak
Sixshooter
Peak
CATARACT
SAN JUAN
Keyhole
Ruin
Horse Canyon
Davis Canyon
Druid Arch
Gothic
Arch
Castle
Arch
Thirteen
Faces
Fortress
Arch
Angel
Arch
Arch
All American
Man
Lavender
Canyon
POWELL
Ruin Park
Natural
Arch
Fisheye
Arch
Natural
Arch
Kirk
Arch
Cleft
Arch
Hand Holt
Arch
Wedding Ring
Arch
Canyon
BEEF BASIN
LAKE
SALT LAKE
CITY
Provo
Price
U T A H
Green
River
Richfield
CANYONLANDS
NATIONAL PARK
Moab
LAKE POWELL

On June 26, 1969, state and local officials met along the Green River at the mouth of Split Mountain Canyon, in Dinosaur National Monument, to dedicate a monument to Major Powell, commemorating the 100th anniversary of his first river trip, and to dedicate the Powell Centennial Scenic Drive, also known as the Powell Memorial Highway. In the absence of any roads closely paralleling the Green and Colorado Rivers except for short distances, this route is virtually the only means of approach to the rivers and comprises parts of several state and federal highways connecting Green River, Wyo., and Grand Canyon, Ariz. A segment of it, U.S. Highway 163, connects Crescent Junction, Moab, Monticello, and Blanding, all in Utah, and provides the principal access routes to Canyonlands and Arches National Parks and Natural Bridges National Monument.

The ceremonies at the mouth of Split Mountain Canyon began with the landing of the official party flotilla of four boats similar to the ones used 100 years earlier by Powell, who was impersonated by a bearded man dressed to resemble the one-armed major. After the dedication, the four boats resumed the voyage down the Green River for another ceremony.

On June 29 a second monument was dedicated at the head of Desolation Canyon, some 50 miles southwest of Vernal, Utah, where the 1869 Powell expedition first ventured into the then unknown wilderness. The bronze plaque identifies Desolation Canyon, named by Powell, as a national historic landmark that comprises 58,000 acres in an area 1 mile wide on each side of a 95-mile reach of the Green River.

Early History

Prehistoric people

There is abundant evidence that the canyon lands were inhabited by cliffdwellers centuries before the explorations of Powell or the earlier visits of the Spanish explorers and the fur trappers. Projectile points and other artifacts found in the nearby La Sal and Abajo Mountains indicate occupation by aborigines from about 3,000-2,000 B.C. to about 1 A.D. (Hunt, 1956).

Archeologists have found evidence of two occupations by prehistoric peoples in and near Canyonlands National Park—the Fremont people around 850 or 900 A.D. and the Pueblo or Anasazi people from about 1075 to their departure in the late 12th century (Jennings, 1970). Within the park, the most densely populated area was along Salt Canyon and its tributaries in the Needles district, but many prehistoric dwellings and granaries are also found just south of the park in Beef Basin and Ruin Park.

The Fremont people, who were mainly hunters, seemingly left no artifacts, but they did leave beautiful pictographs, or rock paintings, such as the group of ghostly human figures on the sandstone wall of Horseshoe Canyon (fig. 2), in the detached unit northwest of the park proper (fig. 1). The All American Man (fig. 3), a most unusual "Humpty Dumpty" figure painted in red, white, and blue on the wall of a cave about 3⅓ miles above the cable across the east fork of Salt Canyon, is believed to have been done in the Fremont style, but as shown in the photograph, it is next to one of three dwellings in the same cave that were built later by the Anasazi people. Tower Ruin (fig. 4) is one of many well-preserved granaries built by the Anasazi, who farmed the flood plains of creeks such as Salt and Horse Canyons. According to Jennings (1970),

PICTOGRAPHS ON WALL OF HORSESHOE CANYON, believed to have been made by Fremont people about 1,000 years ago. Numbered chalkmarks 1 foot apart along bottom were made by some previous photographer. Photograph by Walter Meayers Edwards, 1971 National Geographic Society. (Fig. 2)

THE ALL AMERICAN MAN, on wall of cave in Cedar Mesa Sandstone Member of Cutler Formation along upper Salt Canyon, believed to have been painted by Fremont people. Granary on right was built by Anasazi people. Chalk outline was added by some previous photographer. Photograph by National Park Service. (Fig. 3)

TOWER RUIN, an Anasazi granary in cave in Cedar Mesa Sandstone Member along tributary of Horse Canyon. (Fig. 4)

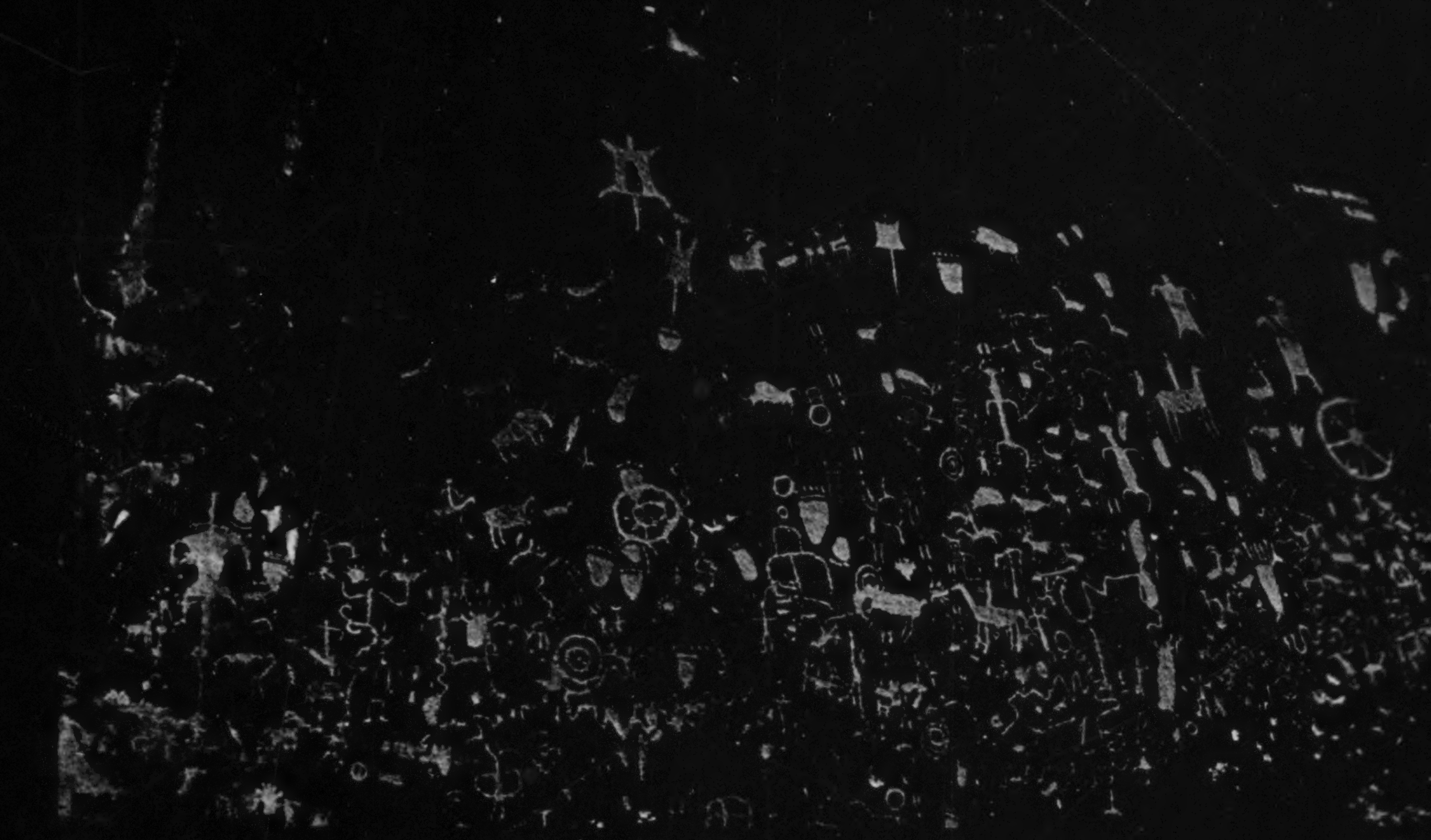
> There is some evidence that these early Utah people practiced a form of irrigation, using shallow ditches to carry water to their crops. There is also evidence that a change in climate sometime around the late 12th century brought about summer flash flooding and induced the cliff dwellers to abandon their Canyonlands homes and farms.

Visitors to the Needles district pass through Indian Creek State Park 12 miles west of U.S. Highway 163. The principal attraction, which is visible at the base of the Wingate Sandstone cliff on the right (north), is Newspaper Rock (fig. 5), one of the best preserved and most intriguing petroglyphs, or rock inscriptions, in the canyon lands. Many of the older cliff faces of the Wingate and Navajo Sandstones are darkened or blackened by desert varnish, a natural pigment of iron and manganese oxides. The prehistoric inhabitants of the canyon country learned that effective and enduring designs could be created simply by chiseling through the thin dark layer to reveal the buff or tan sandstone beneath. According to Jesse D. Jennings (letter of Mar. 20, 1962, to Utah Div. Parks and Recreation),

> There are at least three periods of workmanship visible on the rock. The last is quite recent since it shows men mounted on horses [brought in by Spanish explorers]. These are probably less than 200 years old and are probably the work of Ute tribesmen. The others cannot be identified with any specific cultural group, although the earliest may be as much as one thousand years old and are probably the work of the so-called "Fremont" peoples * * *.

In addition to the designs by the Fremont, Anasazi, and Ute artists, you will note a few names and dates as late as 1954.

NEWSPAPER ROCK, petroglyphs cut in Wingate Sandstone cliff in Indian Creek State Park. Inscriptions probably span about 1,000 years and include figures by Fremont, Anasazi, and Ute people (mounted horsemen) and by a few early white settlers. (Fig. 5) ▷

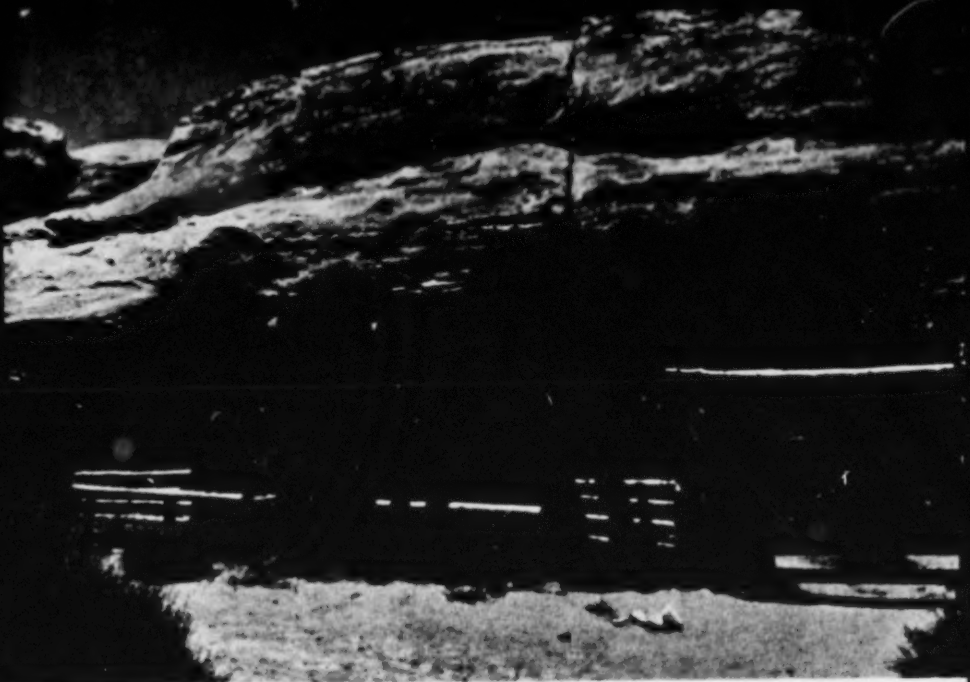


Late arrivals

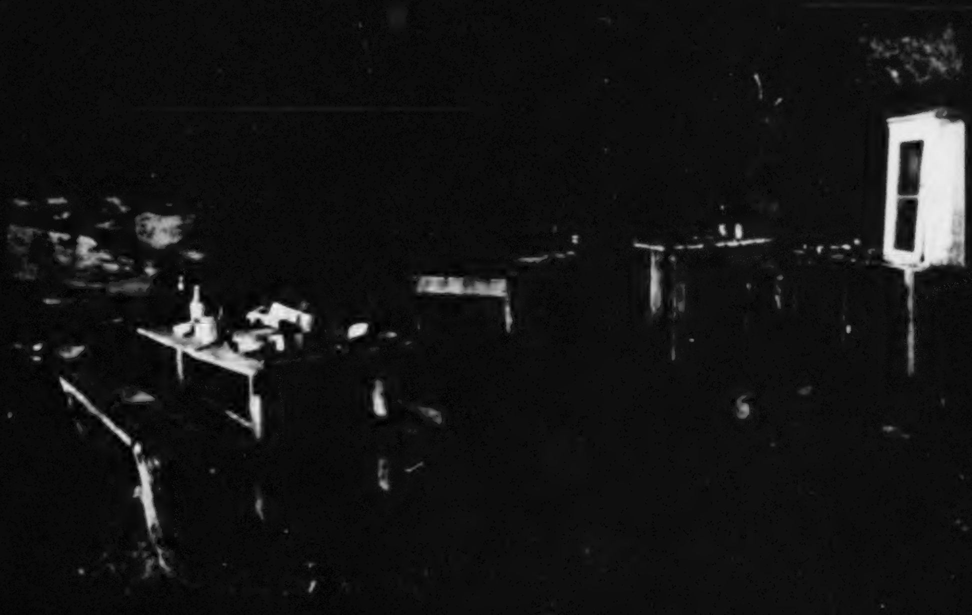
The modern history of Canyonlands is as colorful as the canyons themselves, and involves Indians, cattlemen, bank robbers, cattle rustlers, and horsethieves, followed by oil drillers, uranium hunters, potash miners, jeepsters, boaters, and tourists. A brief summary of their activities is taken mainly from a recent account by Maxine Newell (1970), to whose work you are referred for further details.

Bands of Ute and Navajo Indians roamed the canyons and mesas until the late 1800's, but gradually they were driven out and succeeded by pioneer cattlemen, the first of whom were George and Silas Green in 1874-75, followed by the Taylor brothers in 1880-81. Cowboys named many of the natural features of the area, and the Needles country provided the scenic background for some of Zane Grey's western tales and for David Lavender's "One Man's West." Lavender Canyon, whose headwaters were recently annexed to the park, was named for him. Visitors to the Needles district pass the Dugout Ranch about 7 miles northwest of Newspaper Rock. The earliest ranch dwellings were dirt houses built by the Somerville and Scorup brothers, who bought the huge Indian Creek spread for $426,000 from the Carlisle Co. in 1918. In 1973 the ranch was operated by Robert and Heidi Redd, whose line camp at Cave Spring served as temporary park headquarters and later was restored to a typical line camp (fig. 6) as part of the Cave Spring Environmental Trail.

Robbers Roost Canyon and Spring some 30 miles west of the park was the hangout of a horsethief named Cap Brown in the seventies. From 1884 until about 1900 it was the hiding place for the notorious Butch Cassidy and his Wild Bunch, who robbed banks, trains, and mine payrolls and stole or traded horses and cattle from the ranchers. Cassidy and his gang managed to get along with the cattlemen by either replacing or paying for most of the horses and cattle, but the law finally drove them out, and Butch, the Sundance Kid, and a woman named Etta Place moved to Bolivia. According to the movie version, Butch and the Sundance Kid were hunted down and shot by Bolivian soldiers for robbing banks and mine payrolls, but according to Baker (1971) Butch returned safely to the United States and died in the Northwest in 1943 or 1944, and the Sundance Kid is reported to have died in Casper, Wyo., in 1958 at age 98. Art Ekker (Findley, 1971, fig. 3), present owner of Robbers Roost Ranch, which contains the former hangout, commented: "A lot of people are sure that Butch and his gang buried some money around Robbers



CAVE SPRING LINE CAMP. Above, line-camp exterior, showing entrance and corral; below, interior, showing furnishings and staple food items kept in stock. Served as regular cowboy line camp for many years, than as part of temporary park headquarters; later restored as part of Cave Spring Environmental Trail. A nearby cave, also in Cedar Mesa Sandstone, contains a spring. (Fig. 6)



Roost. Every so often somebody turns up with a map or a metal detector and wants to start digging. They've found a lot of rusty tin cans and old horseshoes."

The uranium boom of the 1950's, touched off by Charlie Steen's fabulous Mi Vida mine south of La Sal, Utah, temporarily skyrocketed the population of Moab and sent uranium hunters into every nook and cranny of the canyon lands. Many of the jeep trails were first made then, and landing strips and prospect holes of that period are plentiful. Most of the prospects were in the Chinle Formation, particularly in the Moss Back Member at the base, but some were in rocks older than the Chinle, and some were in younger rocks. The uranium mines in the park are no longer operating, but production has been resumed in a few mines just north and east of the park. Information on some of these mines, obtained from E. P. Beroni (U.S. Atomic Energy Comm., oral commun., Feb. 14, 1973) is given at appropriate places below.

The number of boaters or floaters on the Colorado and Green Rivers is increasing steadily, and trips by jet boat and other power boats are available from Moab. Tourist travel over good roads on Island in the Sky and Hatch Point and by paved road to The Needles also is increasing steadily. Travel west of the Green River and main stem of the Colorado River is still restricted largely to a few jeep trails and to hiking or horseback riding.

Geographic Setting

Geologists have divided the United States into many provinces, each of which has distinctive geologic and topographic characteristics that set it apart from the others. One of the most intriguing and scenic of these is the Colorado Plateaus province, referred to in this report simply as the Colorado Plateau, or the Plateau. This province, which covers some 150,000 square miles and is not all plateaus, as we shall see, extends from Rifle, Colo., at the northeast to a little beyond Flagstaff, Ariz., at the southwest and from Cedar City, Utah, at the west nearly to Albuquerque, N. Mex., at the southeast. Canyonlands National Park appropriately occupies the heart of the Canyon Lands section, one of the six subdivisions of the Plateau. As the names imply, the Canyon Lands section of the Plateau comprises a high plateau, generally ranging in altitude from 5,000 to 7,000 feet, which has been intricately dissected by literally thousands of canyons.

Canyonlands National Park is drained entirely by the Colorado and Green Rivers, whose confluence is an important and scenic central feature of the park (figs. 59, 60). Individual canyons traversed or drained by these rivers are discussed in later chapters.

When Major Powell reached the confluence in 1869, the river flowing in from the northeast to join the Green River was called the Grand River, and the Green and Grand joined there to form the Colorado River. The Grand River was renamed Colorado River by act of the Colorado State Legislature approved March 24, 1921, and by act of Congress approved July 25, 1921. But the old term still remains in names such as Grand County, Colo., the headwaters region; Grand Valley, a town 16 miles west of Rifle, Colo.; Grand Valley between Palisade and Mack, Colo.; Grand Mesa, which towers more than a mile above the Grand and Gunnison River valleys; Grand Junction, Colo., a city appropriately located at the confluence of the Grand and Gunnison Rivers; Grand County, Utah, which the river traverses after entering Utah; and Grand View Point, the southern terminus of Island in the Sky.

When viewed at a distance of 1 foot, the shaded relief map (fig. 1) shows the general shape of the land surface in and near Canyonlands National Park to the same horizontal scale as it would appear to a person in a spacecraft flying at a height of 250,000 feet, or about 48 miles. This map was prepared by artist John R. Stacy from parts of the reverse sides of four plastic relief maps[2]—Salina, Moab, Cortez, and Escalante quadrangles, at a scale of 1 : 250,000—using a simple time- and money-saving method he devised (Stacy, 1962).

An image of Canyonlands National Park and vicinity from a satellite at a height of about 570 miles is shown in figure 7. Note white clouds and black cloud shadows on right.

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[2] These plastic relief maps, made by the U.S. Army Map Service, can be obtained from the T.N. Hubbard Scientific Co., Box 105, Northbrook, Ill. 60062. Topographic maps at scales of 1:250,000 and 1:62,500 for the entire area, topographic maps at a scale of 1:24,000 for much of the area, and a special topographic map of "Canyonlands National Park and Vicinity" at a scale of 1:62,500 are available from the U.S. Geological Survey, Denver Distribution Section, Federal Center, Denver, Colo. 80225, and from privately owned shops where maps are sold. A revised edition of the latter, including relief shading, will soon be available. An index map of Utah showing all available topographic maps is free upon request to the above address.

CANYONLANDS NATIONAL PARK AND VICINITY, from NASA's unmanned Earth ▷ Resources Technology Satellite (ERTS-1),at height of about 570 miles. The space image map was prepared from simultaneous scanning in three color bands—blue green, red, and near infrared—that were combined to produce a false-color image in which vigorous green vegetation (forests and irrigated areas) appears bright red, water dark blue, and soils and bare rocks various shades of blue, blue green, or yellow green. Bright-blue area on west bank of Colorado River about 10 miles southwest of Moab is the group of large evaporation ponds of Texas Gulf, Inc., shown in figures 31 and 71. Images were taken at 10:31:10 a.m., Aug. 23, 1972, during the 432d orbit, telemetered to Alaska, videotaped, then photographed. Sun elevation was 53 degrees above horizon from azimuth of 130 degrees. Image covers an area about 100 miles square. (See scale.) Location of Monticello is approximate; that of other towns is believed to be correct. Park boundaries are not shown because of difficulty in locating them accurately, but features such as Colorado and Green Rivers can easily be compared with those in figure 1. (Fig. 7).

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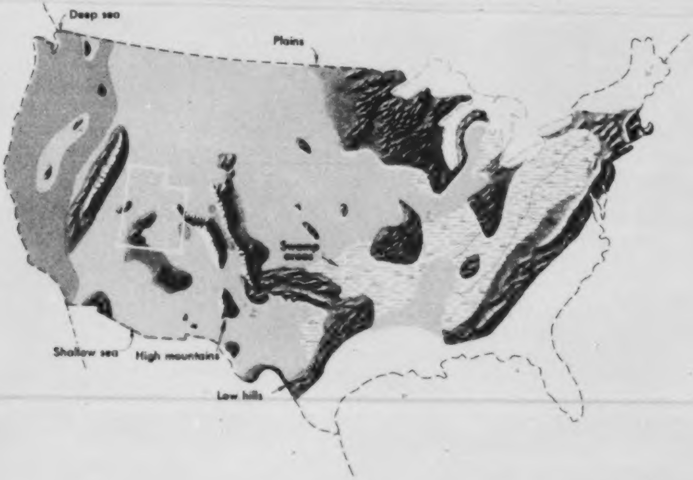
Rocks and Landforms

The vivid and varied colors of the bare rocks and the fantastic canyons, buttes, spires, columns, alcoves, caves, arches, and other erosional forms of the canyon country result from a fortuitous combination of geologic and climatic circumstances and events unequaled in most other parts of the world.

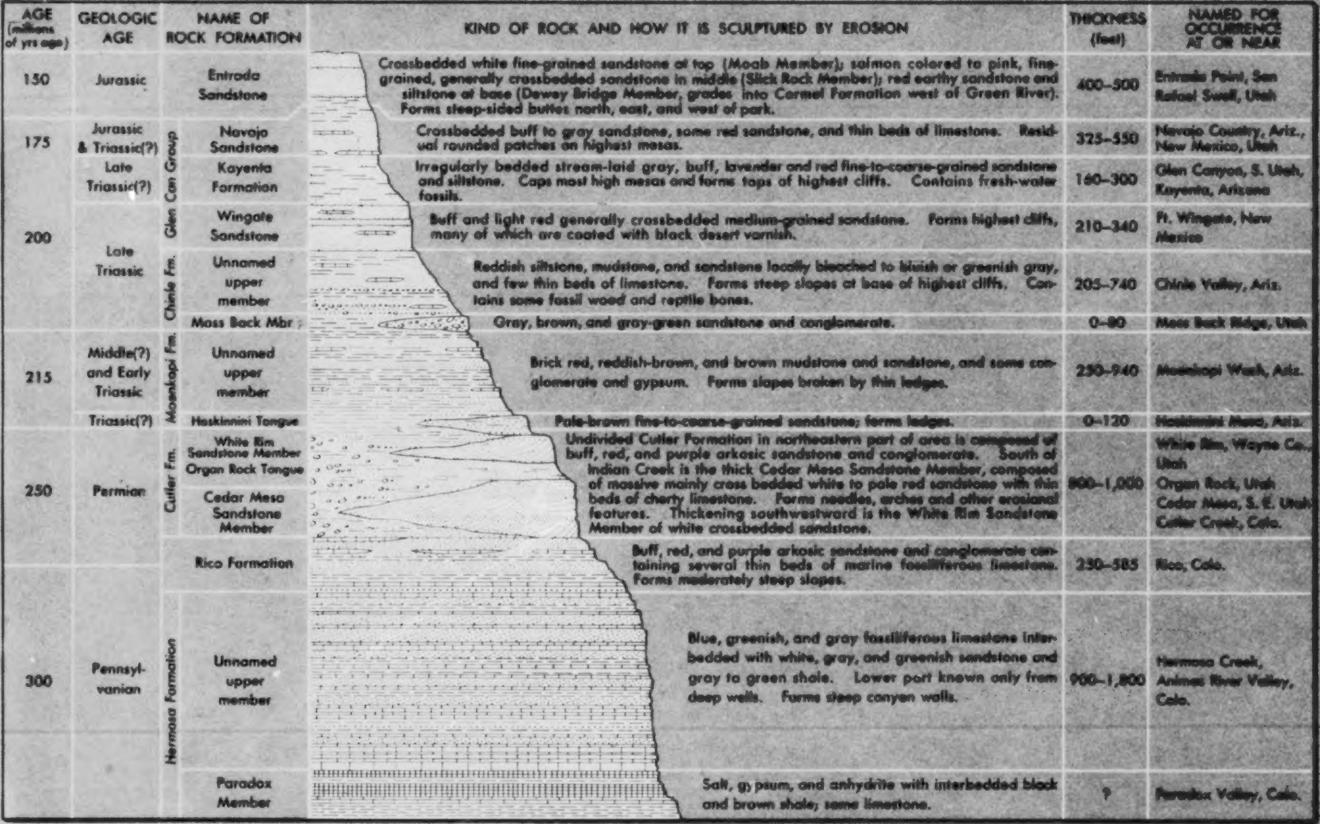
First among these events was the piling up, layer upon layer, of thousands of feet of sedimentary rocks under a wide variety of environments. Sedimentary rocks of the region are composed of particles ranging in size from clay and silt through sand and gravel carried to their resting places by moving water, silt and sand particles transported by wind, and some materials precipitated from water solutions, such as limestone (calcium carbonate), dolomite (calcium and magnesium carbonate), gypsum (calcium sulfate with some water), anhydrite (calcium sulfate alone), common salt (sodium chloride), potash minerals such as potassium chloride, and a few other less common types. Some of the materials were laid down in shallow seas that once covered the area (fig. 8) or in lagoons and estuaries near the sea. Some beds were deposited by streams in inland basins or plains, a few were deposited in lakes, and some, like the Navajo Sandstone, were carried in by the wind. The character and thickness of the sedimentary rocks, and the names and ages assigned to them by geologists, are shown in the rock column in figure 9 and in the cross sections in figures 10 and 15, and the history of their deposition is discussed in the chapter "Summary of Geologic History." The rock column was compiled mainly from generalized stratigraphic sections given by Baker (1933, 1946), McKnight (1940), Hinrichs and others (1967, 1971b), and F. A. McKeown and P. P. Orkild (U.S. Geol. Survey, unpub. data, Mar. 16, 1973).

Not exposed in the area but present far beneath the sedimentary cover, and exposed in a few surrounding places, are examples of the other two principal types of rocks: (1) igneous rocks, solidified from molten rock forced into or above younger rocks along cracks, joints, and faults and (2) much older metamorphic rocks, formed from other pre-existing rock types by great heat and pressure at extreme depths. The particles comprising the sedimentary rocks were derived by weathering and erosion of rocks of all three types in the headwater regions of the ancestral Colorado River basin. Igneous rocks of Tertiary Age (fig. 80) form the nearby La Sal, Abajo, and Henry Mountains (fig. 7).

Second among the main events leading to the formation of the canyon country was the raising and buckling of the Plateau by earth forces so that it could be vigorously attacked by various forces of erosion and so that the rock materials thus pried loose or dissolved could eventually be carted away to the Gulf of California by the ancestral Colorado River. Some idea of the enormous volume of rock thus removed is apparent when you look down some 2,000 feet to the river from any of the high overlooks, such as Dead Horse Point (fig. 15) or Green River Overlook (fig. 23), or when you lay a straightedge across the three high mesas in figure 10 and note the large volume of missing rocks below. Not so apparent, however, is the fact that some 10,000 feet of younger Mesozoic and Tertiary rocks that once overlay this high plateau also has been swept away. In all, the river has carried thousands of cubic miles of sediment to the sea and is still actively at work on this gigantic earthmoving project. In an earlier report (Lohman, 1965, p. 42) I estimated that the rate of removal may have been as great as about 3 cubic miles



SHALLOW INLAND SEA which covered Canyonlands and vicinity during Middle Pennsylvanian time. (Fig. 8)



AGE (millions of yrs ago)	GEOLOGIC AGE		NAME OF ROCK FORMATION	KIND OF ROCK AND HOW IT IS SCULPTURED BY EROSION	THICKNESS (feet)	NAMED FOR OCCURRENCE AT OR NEAR
150	Jurassic		Entrada Sandstone	Crossbedded white fine-grained sandstone at top (Moab Member); salmon colored to pink, fine-grained, generally crossbedded sandstone in middle (Slick Rock Member); red earthy sandstone and siltstone at base (Dewey Bridge Member, grades into Carmel Formation west of Green River). Forms steep-sided buttes north, east, and west of park.	400–500	Entrada Point, San Rafael Swell, Utah
175	Jurassic & Triassic(?)	Glen Can Group	Navajo Sandstone	Crossbedded buff to gray sandstone, some red sandstone, and thin beds of limestone. Residual rounded patches on highest mesas.	325–550	Navajo Country, Ariz., New Mexico, Utah
	Late Triassic(?)		Kayenta Formation	Irregularly bedded stream-laid gray, buff, lavender and red fine-to-coarse-grained sandstone and siltstone. Caps most high mesas and forms tops of highest cliffs. Contains fresh-water fossils.	160–300	Glen Canyon, S. Utah, Kayenta, Arizona
200	Late Triassic		Wingate Sandstone	Buff and light red generally crossbedded medium-grained sandstone. Forms highest cliffs, many of which are coated with black desert varnish.	210–340	Ft. Wingate, New Mexico
		Chinle Fm.	Unnamed upper member	Reddish siltstone, mudstone, and sandstone locally bleached to bluish or greenish gray, and few thin beds of limestone. Forms steep slopes at base of highest cliffs. Contains some fossil wood and reptile bones.	205–740	Chinle Valley, Ariz.
			Moss Back Mbr	Gray, brown, and gray-green sandstone and conglomerate.	0–80	Moss Back Ridge, Utah
215	Middle(?) and Early Triassic	Moenkopi Fm.	Unnamed upper member	Brick red, reddish-brown, and brown mudstone and sandstone, and some conglomerate and gypsum. Forms slopes broken by thin ledges.	250–940	Moenkopi Wash, Ariz.
	Triassic(?)		Hoskinnini Tongue	Pale-brown fine-to-coarse-grained sandstone; forms ledges.	0–120	Hoskinnini Mesa, Ariz.
250	Permian	Cutler Fm.	White Rim Sandstone Member Organ Rock Tongue Cedar Mesa Sandstone Member	Undivided Cutler Formation in northeastern part of area is composed of buff, red, and purple arkosic sandstone and conglomerate. South of Indian Creek is the thick Cedar Mesa Sandstone Member, composed of massive mainly cross bedded white to pale red sandstone with thin beds of cherty limestone. Forms needles, arches and other erosional features. Thickening southwestward is the White Rim Sandstone Member of white crossbedded sandstone.	800–1,000	White Rim, Wayne Co., Utah Organ Rock, Utah Cedar Mesa, S. E. Utah Cutler Creek, Colo.
			Rico Formation	Buff, red, and purple arkosic sandstone and conglomerate containing several thin beds of marine fossiliferous limestone. Forms moderately steep slopes.	230–585	Rico, Colo.
300	Pennsylvanian	Hermosa Formation	Unnamed upper member	Blue, greenish, and gray fossiliferous limestone interbedded with white, gray, and greenish sandstone and gray to green shale. Lower part known only from deep wells. Forms steep canyon walls.	900–1,800	Hermosa Creek, Animas River Valley, Colo.
			Paradox Member	Salt, gypsum, and anhydrite with interbedded black and brown shale; some limestone.	?	Paradox Valley, Colo.

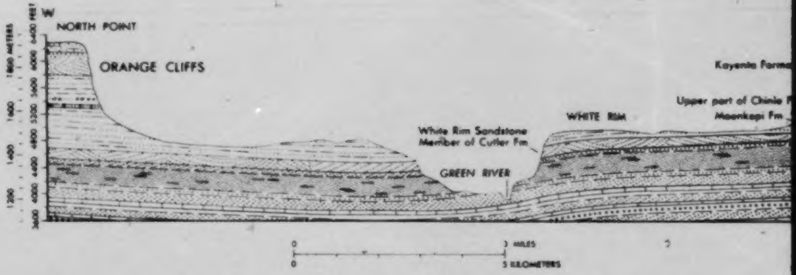
ROCK COLUMN OF CANYONLANDS NATIONAL PARK. One foot equals 0.305 meter. (Fig. 9) each century. For a few years the bulk of it was dumped into Lake Mead, but now Lake Powell is getting much of it. When these and other reservoirs ultimately become filled with sediment, for reservoirs and lakes are but temporary things, the Gulf of California will again become the burial ground.

Last but far from least among the factors responsible for the grandeur of the canyon country is the desert climate, which allows us to see virtually every foot of the vividly colored naked rocks and has made possible the creation and preservation of such a wide variety of fantastic sculptures. A wetter climate would have produced a far different and smoother landscape in which most of the rocks and land forms would have been hidden by vegetation. In the canyon lands the vegetation is mainly on the high mesas and on the narrow flood plains bordering the rivers, but scanty vegetation does grow on the gentle slopes or flats.

The desert climate has combined with the nearly flat lying layers of sediments of different character, hardness, and thickness to produce steep slopes having many cliffs and ledges and generally sharp to angular edges rather than the subdued rounded forms of more humid regions. This has led geologists to refer to such terrain as having "layer-cake geology," and this is brought out by the profile in the rock column (fig. 9), by the cross section (fig. 10), by figure 15, and by many of the other photographs. But the baker of this cake was rather careless—not only do the layers range widely in thickness and character, but some are wedge shaped, thick on one side of the cake but thin or absent on the other. Then too, when he ran out of icing in the midst of a layer, he was apt to finish with a different kind or color, for no inspector was on the job to insure orderly construction.

If all the rock strata in the park were present at one locality, their sequence and thickness would be those shown on the right-hand side of the graphic section in figure 9. However, because of the lateral changes in thickness and character and the wedging out of certain beds, such as the White Rim Sandstone Member of the Cutler Formation, no two sections of the strata are exactly alike. This will be brought out in photographs of different exposures of rocks in various parts of the park.

An often-asked question is, why are most of the rocks so red? This can be answered by one word—iron, the same pigment used in rouge and in paint for barns and boxcars. Various oxides of iron, some including water, produce not only brick red but also pink, salmon, brown, buff, yellow, and even green or bluish green. This does not imply that the rocks could be considered as

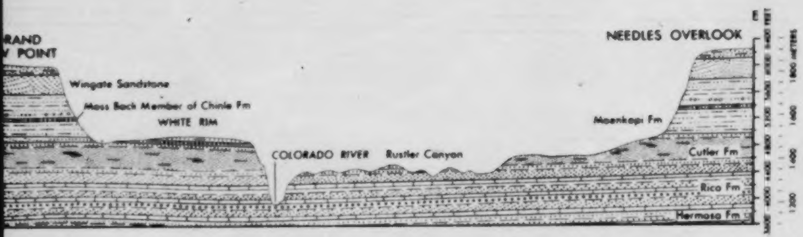


sources of iron ore, for the merest trace of iron, generally only 1 to 3 percent, is enough to produce even the darkest shades of red. The only rocks in the park that contain virtually no iron are white sandstones of the White Rim Sandstone Member of the Cutler Formation (figs. 21-24) and the Navajo Sandstone.

As pointed out by Stokes (1970, p. 3), microscopic examination of the colored grains of quartz or other minerals shows the pigment to be merely a thin coating on and between white or colorless particles. Sand or silt weathered from such rocks soon loses its color by the scouring action of wind or water, so most of the sand dunes and sand bars are white or nearly so.

The map (fig. 1) and cross section (fig. 10) of the park show that in general the major features of the landscape lie at three different and distinctive levels. A recently erected plaque on Grand View Point appropriately refers to these levels as the "Three Worlds." The high plateaus, or mesas, in and adjoining the park dominate the skyline—in fact, the central one, between the Green and Colorado Rivers, is appropriately named Island in the Sky. If you stand on either the east or the west shore of this towering cliff-bordered island, you can look across a sea of fantastic erosional forms to a similar cliff-bordered shore at about the same level. Closer inspection of the sea of rocks on either side shows relatively flat benches or platforms about halfway to the bottom; below these are the generally steep sided or cliff-bordered canyons of the two rivers and their larger tributaries. From some vantage points along the shore, such as Dead Horse Point (fig. 15) or Green River Overlook (fig. 23), you can see the deepest level of all—the channels and flood plains of the Green and Colorado Rivers.

What caused the "Three Worlds" and the formidable cliffs supporting the high mesas or forming towering monoliths like Angel Arch or Druid Arch (figs. 43, 54)? Differences in the composition, hardness, arrangement, and thickness of the rock layers determine their ability to withstand the forces of fracturing and



SECTION ACROSS CANYONLANDS NATIONAL PARK from North Point at west (left), via Grand View Point in middle, to Needles Overlook at east (right), showing the three principal topographic levels and character of the rock strata. Line of section bends at Grand View Point, which is northernmost part. (Fig. 10)

erosion and hence their tendency to form cliffs, ledges, or slopes. Most of the cliff- or ledge-forming rocks are sandstones consisting of sand grains deposited by wind or water and later cemented together by silica (SiO_2), calcium carbonate ($CaCO_3$), or one of the iron oxides (such as Fe_2O_3), but some hard, resistant ledges are made of limestone (calcium carbonate). The rock column (fig. 9) shows in general how these rock formations are sculptured by erosion and how they protect underlying layers from more rapid erosion. The nearly vertical cliffs supporting the highest mesas consist of the well-cemented Wingate Sandstone protected above by the even harder sandstone of the Kayenta Formation. To borrow from an earlier report of mine (Lohman, 1965, p. 17),

> Vertical cliffs and shafts of the Wingate Sandstone endure only where the top of the formation is capped by beds of the next younger rock unit—the Kayenta Formation. The Kayenta is much more resistant than the Wingate, so even a few feet of the Kayenta * * * protect the rock beneath.

In some places remnants of the overlying Navajo Sandstone make up the topmost unit of the cliff.

How to See the Park

The question of how to see the park has no simple answer, for the park is too vast and complex to comprehend by a quick visit to any one of its many and varied parts or by any one means of transportation. Some, as did Major Powell, view it only from the rivers—by boat plus a few back-breaking climbs up the bordering canyon walls. Others see only the small parts reachable by passenger cars. The more venturesome see vastly more by jeep, foot, or horseback. And a few prefer to view it as the birds do—from the air. Many, those who put aside their magazines long enough, get bird's-eye views without half trying, for Canyonlands is beneath the principal air routes connecting Los Angeles with Grand Junction and Denver. Actually, a full appreciation of all the wonders and beauties of the park is possible only by combining all these approaches and methods of locomotion, but only a few fortunate souls such as Bates Wilson have thus been able to inspect virtually every square foot of it.

The task clearly before me, then, is how best to present such a complex wonderland to you, the reader. The method I selected, after considerable thought and a few false starts, is to begin at the top—the high mesas—and work my way downward much as the rivers have done in carving out this fantastic area, to some of the broad benchlands beneath the mesas and eventually to the river channels and deep canyons. Although the approach I selected may not be the best, and admittedly is but one of several that comes to mind, I hope it gets the job done.

The High Mesas

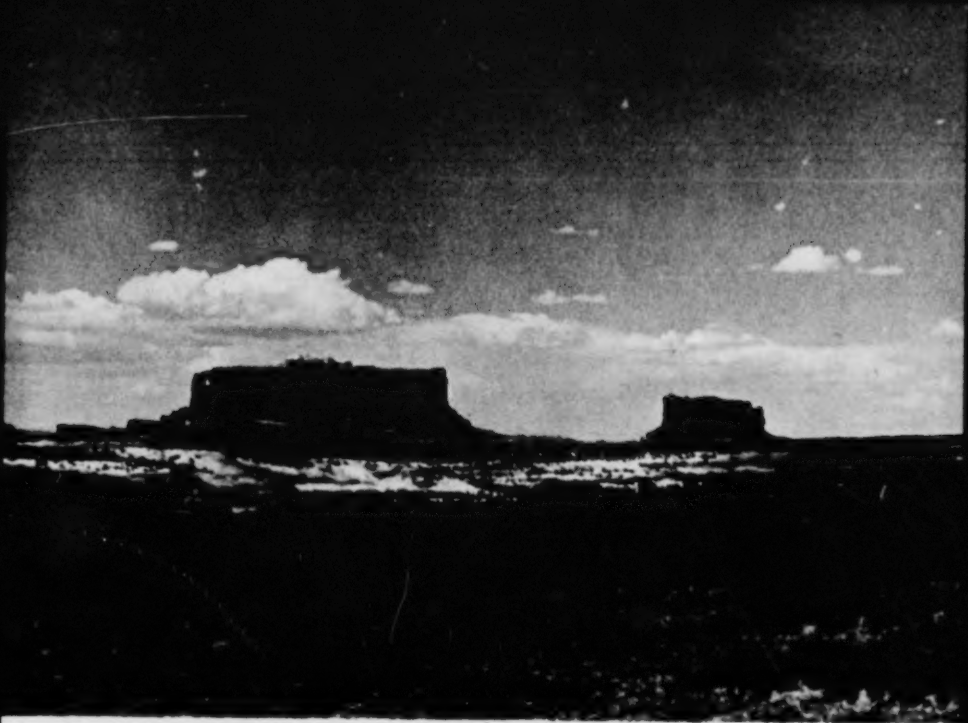
Even though the "peninsular" mesas east and west of Island in the Sky, known respectively as Hatch Point and the Orange Cliffs, lie outside the present boundaries, they provide breathtaking views of important features within the park, so brief descriptions of them are included below. But first, let us take a closer look at Island in the Sky.

Island in the Sky

As the map (fig. 1) shows, Island in the Sky is really a fork of a wedge-shaped peninsula extending southward between the two rivers. An outlier to the south named Junction Butte has already been severed from the main peninsula by erosion and now is a true island. (See frontispiece and fig. 22.) A large chunk of Island in the Sky south of The Neck was about to be severed by erosion from the main peninsula to become a true island, when recent widening and grading of the road gave it a temporary reprieve. When my family and I first squeaked over this narrow neck in 1960 by jeep, furtive glances to right or left showed the two canyons perilously close, and complete severance seemed imminent. The road builders have staved off disaster for a few thousand years, but ultimately the large section to the south will become another island, and a bridge will be required to connect it to the mainland. Its appearance from the air before the road widening is shown in figure 11.

AERIAL VIEW OF THE NECK AND SHAFER TRAIL, looking southwest, taken before rebuilding of park road on mesa top. Cliff-walled canyon to right of The Neck, in middle, drains westward to the Green River; south fork of Shafer Canyon to left drains eastward to Colorado River. This is the narrowest part of Island in the Sky. Photograph by National Park Service. (Fig. 11)

The entrance road to Island in the Sky intersects U.S. Highway 163 at a point 10 miles northwest of Moab, or 21 miles southeast of Crescent Junction on Interstate Highway 70. From U.S. 163 a paved road climbs colorful Sevenmile Canyon past sandstone cliffs of the Wingate, Kayenta, and Navajo Formations to reach the high mesa. There, just "offshore" to the north, are anchored the "battleships" that guard the island—Merrimac and Monitor Buttes (fig. 12). These landmarks are composed of the Entrada Sandstone—the same rock that forms Church Rock at the entrance to the Needles district (fig. 37) and that shapes the spectacular arches in Arches



MERRIMAC (LEFT) AND MONITOR BUTTES guard north entrance to Island in the Sky. White rock near middle is Navajo Sandstone. Buttes comprise all three members of Entrada Sandstone: remnant white top of Moab Member, vertical cliffs of Slick Rock Member, and sloping base of Dewey Bridge Member. (Fig. 12)

National Park. All three members of the Entrada (Wright and others, 1962), as noted in the figure 12 caption, are present here as well as at Church Rock. Eleven miles from the junction with U.S. Highway 163 a graded road to the right, called Horsethief Trail, goes 16 miles down to the Green River, where it connects with roads following the river both upstream and downstream. The road upstream leads to two uranium mines in the lower part of Mineral Canyon which were reactivated in 1972 and 1973. The switchbacks are quite spectacular and are reminiscent of the Shafer Trail. Three miles south of the Horsethief Trail turnoff is a fork in the road—to the left the pavement continues to Dead Horse Point, and straight ahead a graded road leads southward to the Island in the Sky district of Canyonlands National Park.

Most of Island in the Sky has a scattered growth of piñon and juniper trees, but several large flat areas, such as Grays Pasture, contain sufficient sandy soil to support a mantle of grass and weeds, which is used for grazing; however, grazing in this part of the park will be discontinued in 1975.

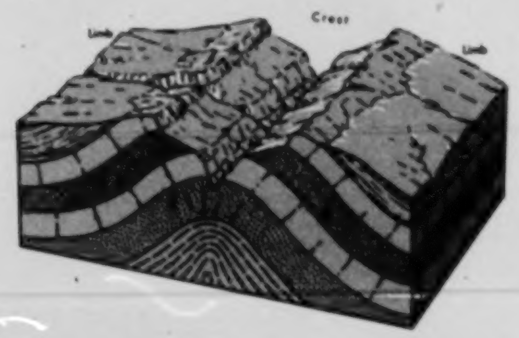
DEAD HORSE POINT STATE PARK

Let us follow the paved road from U.S. Highway 163 all the way to Dead Horse Point, which was set aside as a state park in 1957. The park has a visitor center, museum, modern campgrounds and picnic facilities, and piped water, which is hauled all the way from Moab. An entrance fee of $1 permits us to drive across the narrow neck to a parking area near the point proper, which is protected by stone walls and is provided with a ramada, benches, paths, and sanitary facilities. From Dead Horse Point we get breathtaking views in several directions, including a loop of the Colorado River called the Goose Neck, 2,000 feet nearly straight down.

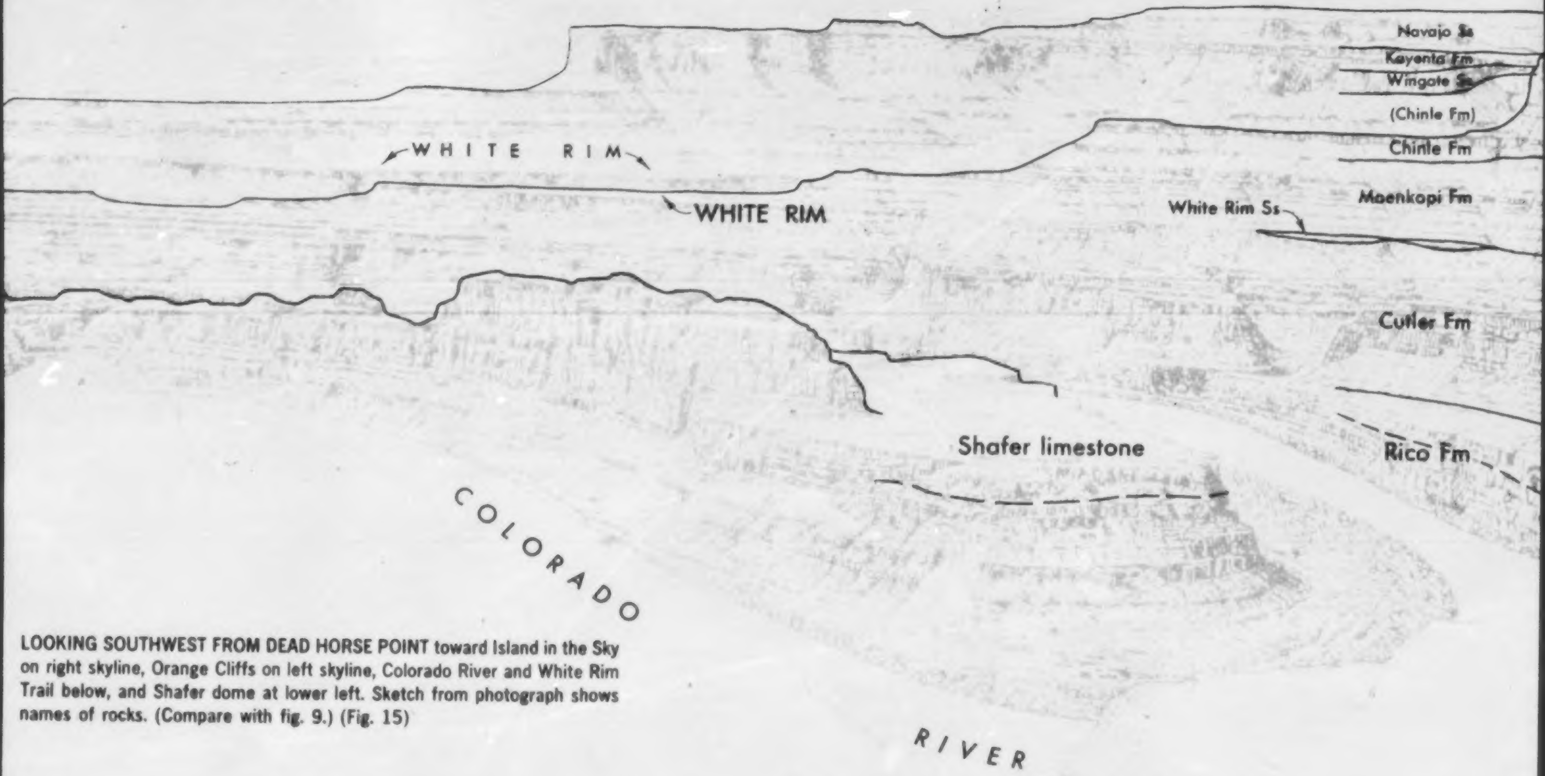
CANE CREEK ANTICLINE, looking northeast toward the La Sal Mountains from Dead Horse Point. Colorado River cuts across crest at middle right, above which is Anticline Overlook. (See fig. 31.) Jeep trail and part of Shafer dome lie below. (Fig. 13)

How did such a magnificent viewpoint get such a macabre name? Dead Horse Point was named for a sad but colorful legend concerning a band of wild horses that once roamed the high mesas. The point is really an embryo island separated from the mainland by a narrow neck barely wide enough for the present road. In the early cowboy days the island was used as a natural corral in which wild mustangs were penned up behind a short fence across the neck so that the better ones could be sorted out and driven to mines in the San Juan Mountains of Colorado. A band of horses corralled too long without water allegedly died of thirst within sight of the river 2,000 feet below, hence the name of the point, or at least so one version of the story goes. Some versions allude to the wranglers as cowboys; others, as horsethieves.

To the northeast we can see the Cane Creek anticline—an upward fold of the rocks—behind which loom the La Sal Mountains (fig. 13). A cutaway view of a typical anticline is shown in figure 14. A better view of the Cane Creek anticline can be seen from Anticline Overlook, as shown in figure 31. From our vantage point at Dead Horse Point, we can see much of Hatch Point, including Anticline Overlook, by looking east and southeast. Spectacular views of the northern part of Canyonlands National Park lie to the south, southwest, and east. Looking southwest (fig. 15), we see most of the rock formations exposed in Canyonlands—more than can be seen from any other vantage point in or near the park. The names of the visible rock units shown in figure 15 can be compared with the complete list in the rock column (fig. 9). Parts of Shafer dome, a "closed" rounded anticline, are visible in the lower left of figure 15 and in the lower right of figure 13. Its general domelike shape is outlined by the bluish-white Shafer limestone, a marker bed which also caps the bench on the peninsula within the Goose Neck of the river. This limestone, which here forms the top of the Rico Formation, is not shown in the rock column (fig. 9) because its exposure is limited to the Shafer dome and the Cane Creek anticline and its name is used only locally by prospectors for oil and gas.



CUTAWAY VIEW OF ANTICLINE, or upfold of the rocks. From Hansen (1969, p. 31). (Fig. 14)



LOOKING SOUTHWEST FROM DEAD HORSE POINT toward Island in the Sky on right skyline, Orange Cliffs on left skyline, Colorado River and White Rim Trail below, and Shafer dome at lower left. Sketch from photograph shows names of rocks. (Compare with fig. 9.) (Fig. 15)

Note that the White Rim Sandstone Member of the Cutler Formation, referred to hereinafter simply as the White Rim Sandstone, becomes thinner toward the right (northeast) in figure 15 but is absent entirely in figure 13, just a short distance to the northeast. The gradual disappearance of recognizable beds of this type toward the northeast, including the disappearance of some limestone beds containing marine fossils, are examples of what geologists call facies changes. Here the changes result from the fact that while strata were being deposited in or near ancient seas that lay to the southwest, beds of different character were being laid down on land by streams emanating from the northeast. This will be gone into in more detail in discussions that accompany illustrations to follow, particularly figures 27, 31, and 35.

NORTH ENTRANCE

The north entrance to the Island in the Sky district of Canyonlands National Park used to be 6 miles south of the junction with the paved road to Dead Horse Point, but since the land additions of November 1971, it is only 4½ miles south of this junction. A temporary trailer-housed entrance station marks the old boundary.

SHAFER AND WHITE RIM TRAILS

During the early 1950's a remarkable but hair-raising road known as Shafer Trail was cut down the face of the cliffs below The Neck to reach the C Group of uranium claims near the head of Lathrop Canyon. It branches southward from the park road a mile south of the new entrance, then descends in a series of switchbacks. The aerial view (fig. 11) shows the upper trail and The Neck before the park road was graded and widened, and a view from near The Neck (fig. 16) shows the precipitous cliffs the trail descends. It follows the general route of an old foot trail.

Shafer Trail connects with the White Rim Trail, which, as the name suggests, is built mainly on the White Rim, after which the White Rim Sandstone was named. The White Rim Trail can be followed northeastward to join the pavement at Potash, or it can be followed southward along the Colorado River canyons to

SHAFER TRAIL, from just south of The Neck (figs. 1, 11). Navajo Sandstone is above ▷ road at left, Kayenta Formation forms upper half of cliff below road, and Wingate Sandstone forms lower, vertical half of cliff; lower part of road is in Chinle Formation. (Fig. 16)

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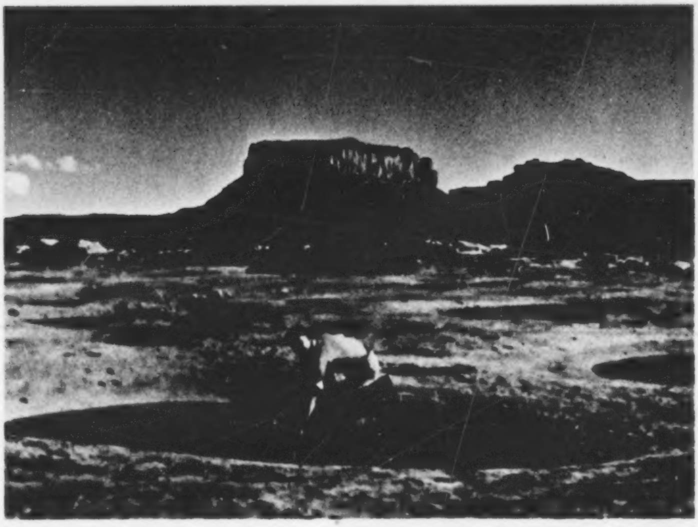
Junction Butte, thence northward along Stillwater and Labyrinth Canyons of the Green River to and beyond the northern boundary of the park. At Horsethief Bottom, you can leave the canyon by Horsethief Trail and rejoin the paved road leading northward to U.S. 163. At Lathrop Canyon, 8 or 10 miles south of where Shafer Trail meets the White Rim Trail, a branch of the White Rim Trail leads downward to the Colorado River, where picnic tables and sanitary facilities are provided. This is used as a lunch stop by some boating groups.

Although some two-wheel-drive cars or trucks have traversed the White Rim and Shafer Trails, they may encounter trouble with deep sand, washouts, or fallen rocks, so four-wheel-drive vehicles are recommended. In the summer these trails should not be attempted without plenty of water, and two vehicles traveling together provide an added margin of safety. All vehicles should carry emergency equipment including a shovel, tow chain or rope, jack, tire tools, and other necessary items. Geologists and uranium prospectors working along the White Rim Trail have obtained good drinking water from small springs that flow from the base of the White Rim Sandstone in many places (Neal Hinrichs, U.S. Geol. Survey, oral commun., Feb. 1973). After rains, runoff gathers in large potholes in the White Rim Sandstone in some places and affords emergency drinking water. Several such potholes filled with water are shown in figure 17. Some potholes occur also in the Cedar Mesa Sandstone in the Needles district.

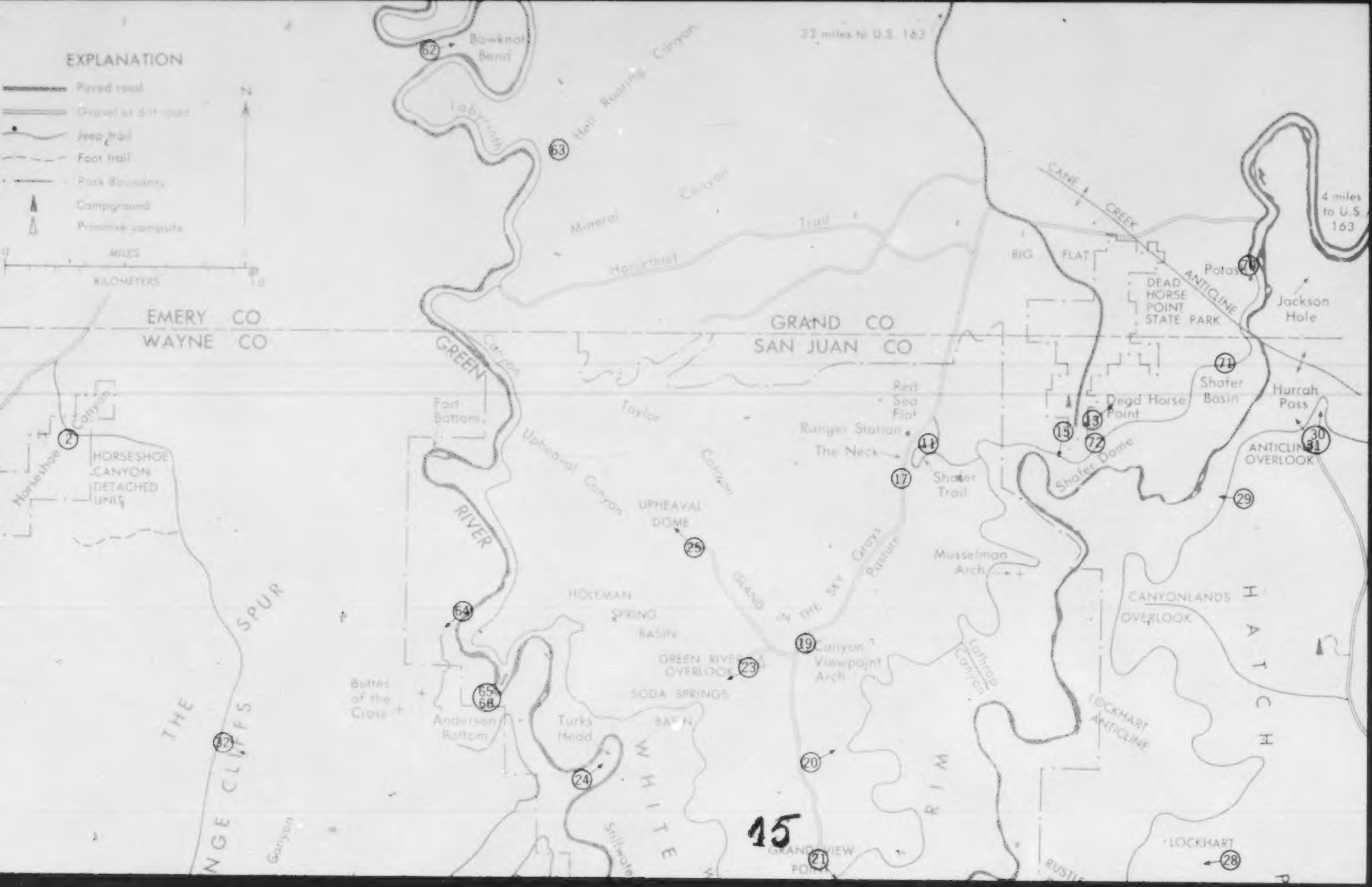
GRAND VIEW POINT

About a mile southwest of The Neck, the road crosses Grays Pasture—the widest and flattest part of Island in the Sky. The drive over this flat grassland yields not the slightest hint of the awesome cliff-walled chasms on either side of the island. Some 5 miles southwest of The Neck, both the island and the road branch like a Y. At a point 0.4 mile north of the Y, Mesa Trail leads one-quarter mile east to Canyon Viewpoint Arch, which frames the Colorado River canyon and the La Sal Mountains (fig. 18). This arch, at the very top edge of the cliff, is composed of the lower part of the Navajo Sandstone. The only other arch of Navajo Sandstone in or near the park that I know of is the small one shown in figure 33, but of course there may be others.

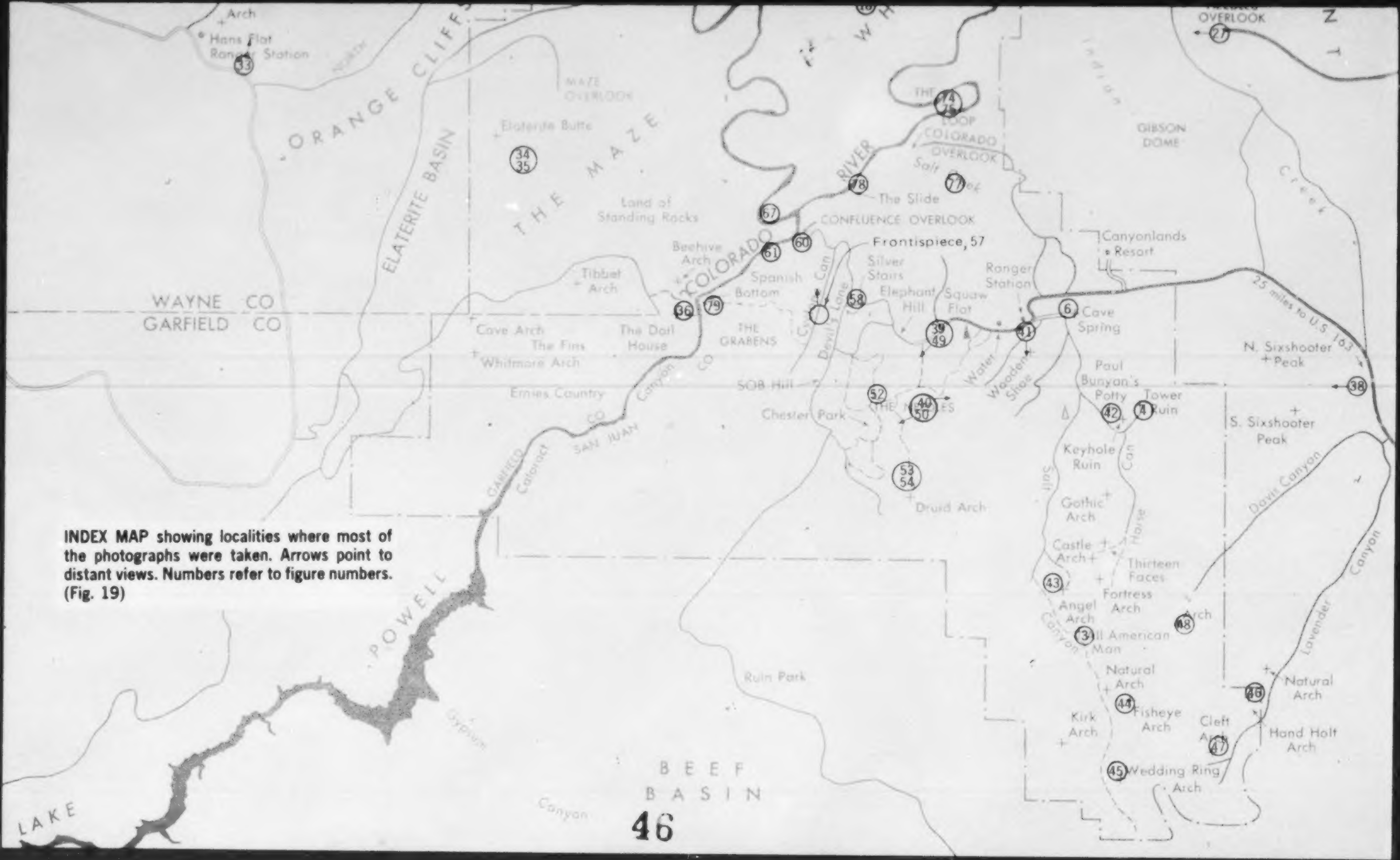
CANYON VIEWPOINT ARCH, framing Colorado River canyon at east end of Mesa Trail ▷ 0.4 mile north of Y in Island in the Sky road. Arch is in lower part of Navajo Sandstone. (Fig. 18)



NATURAL TANKS, filled with runoff from rain, serve as emergency sources of drinking water. Largest tank in foreground contains 4 feet of water and small fresh-water shrimp. So-called tanks, or potholes, are formed partly by water dissolving the calcium carbonate cement and partly by wind or water removing the resulting loose sand grains. View is north toward Junction Butte from point about a mile south of the White Rim Trail. Red rocks in hill on right are in lower part of Moenkopi Formation. Photograph by E. N. Hinrichs. (Fig. 17)


EXPLANATION
Paved road
Gravel or dirt road
Jeep trail
Foot trail
Park Boundary
Campground
Primitive campsite
0
MILES
KILOMETERS
10
N
Bowknot Bend
62
22 miles to U.S. 163
Labyrinth
Hell Roaring Canyon
63
Mineral Canyon
Horsethief Trail
CANE CREEK ANTICLINE
BIG FLAT
Potash
70
4 miles to U.S. 163
DEAD HORSE POINT STATE PARK
Jackson Hole
EMERY CO
WAYNE CO
GRAND CO
SAN JUAN CO
GREEN RIVER
Canyon
71
Shafer Basin
Hurrah Pass
Fort Bottom
Taylor Canyon
Red Sea Flat
Ranger Station
The Neck
11
17
Dead Horse Point
13
15
72
Shafer Dome
30
31
ANTICLINE OVERLOOK
2
Horseshoe Canyon
HORSESHOE CANYON DETACHED UNIT
Upheaval Canyon
UPHEAVAL DOME
25
Shafer Trail
29
Musselman Arch
THE SPUR
HOLEMAN SPRING BASIN
ISLAND IN THE SKY
Grays Pasture
CANYONLANDS OVERLOOK
HATCH
64
19
Canyon Viewpoint Arch
GREEN RIVER OVERLOOK
23
Lathrop Canyon
Buttes of the Cross
65
66
Anderson Bottom
SODA SPRINGS BASIN
Turks Head
LOCKHART ANTICLINE
ORANGE CLIFFS
32
WHITE RIM
20
24
Canyon
Stillwater
GRAND VIEW POINT
21
LOCKHART
28
RUSTLER

15



INDEX MAP showing localities where most of the photographs were taken. Arrows point to distant views. Numbers refer to figure numbers. (Fig. 19)

THE WHITE RIM, looking northeast toward La Sal Mountains from overlook 3 miles north of Grand View Point. White Rim Sandstone here is thicker than near Dead Horse Point (fig. 15) but thinner than in Monument Basin and Stillwater Canyon (figs. 21, 23). (Fig. 20)

Let us now take the branch south of the Y and follow the narrow crest of Grand View Point for about 6 miles to the main overlook. About 0.9 mile south of the Y, a short walk to the west over the lower part of the Navajo Sandstone affords a magnificent view of Stillwater Canyon of the Green River, including Turks Head (figs. 23, 24). Half way to the point is a parking area and overlook, from which we get a spectacular view of canyons cutting the White Rim and of the La Sal Mountains beyond (fig. 20). Note that the White Rim Sandstone, which forms the broad bench appropriately named the White Rim, is here much thicker than where seen near Dead Horse Point (fig. 15).

Three more miles southward takes us to Grand View Point and its nearby picnic area. Though named after the former Grand River some 2,000 feet below, Grand View Point has a double meaning, for we see from here a truly grand view (fig. 21)! At our feet is spectacular Monument Basin, cut below the White Rim into the brick-red Organ Rock Tongue of the Cutler Formation. The White Rim Sandstone here is slightly thicker than to

MONUMENT BASIN FROM GRAND VIEW POINT, Needles Overlook on left skyline, Abajo ▷ Mountains on right skyline. Red spires and cliffs in basin are Organ Rock Tongue of Cutler Formation. (Fig. 21)

the northeast (fig. 20) but thinner than to the west (fig. 23), because it forms a wedge-shaped body that thickens westward. In the distance southeastward are the Abajo Mountains, just west of Monticello, Utah. The prominent projection on Hatch Point on the left skyline is Needles Overlook, from which the photograph in figure 27 was taken. A closeup view of Monument Basin, showing Junction Butte and Grand View Point in the background, is shown in figure 22. The slender spire in the foreground has a measured height of 305 feet (Findley, 1971, p. 78).

MONUMENT BASIN FROM THE AIR, looking north to Junction Butte and Grand View Point. Spire of Organ Rock Tongue in foreground is 305 feet high. White top of Cedar Mesa Sandstone is at bottom of photograph. Photograph by National Park Service (Fig. 22)

GREEN RIVER OVERLOOK

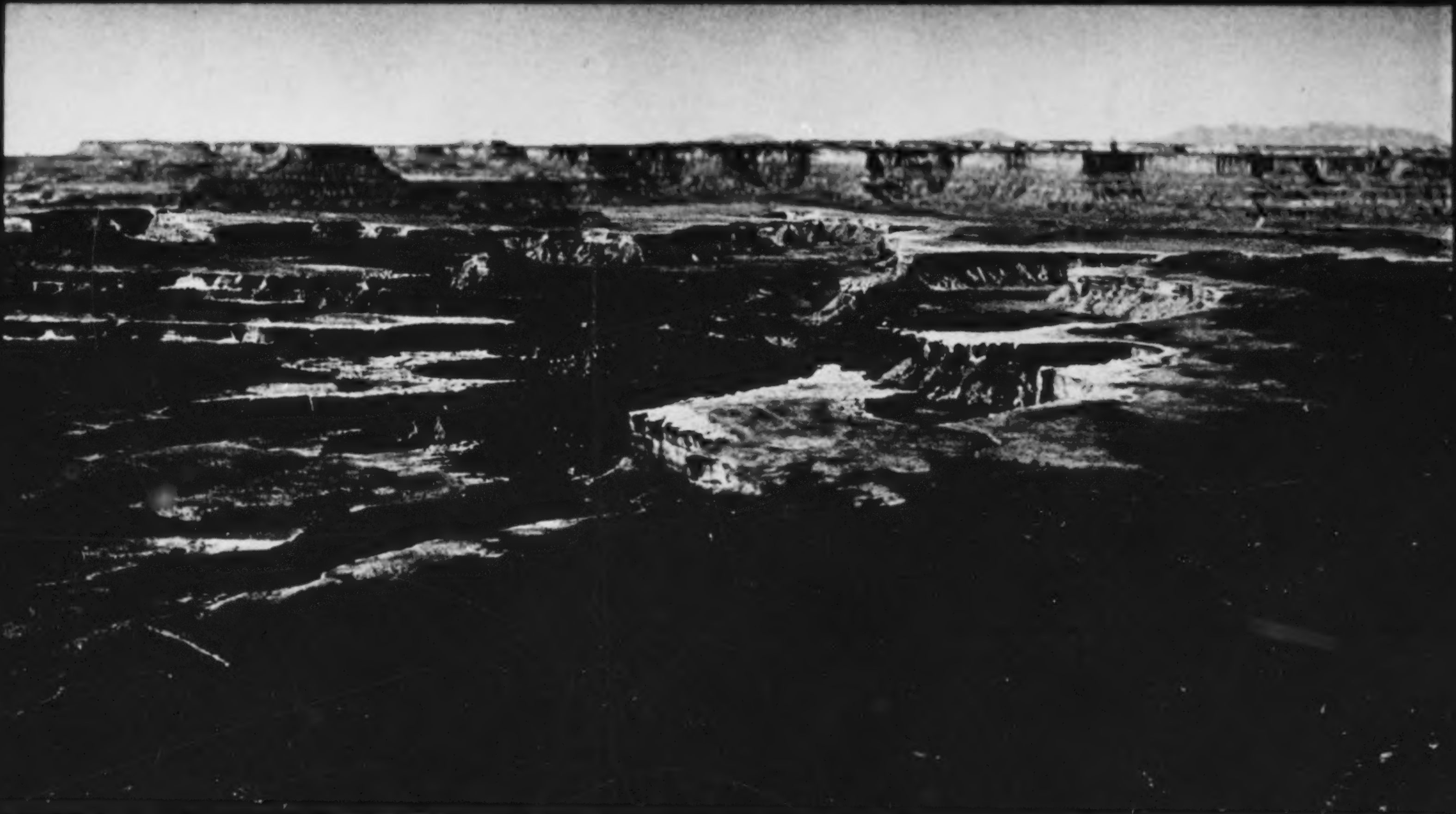
About a quarter mile west of the Y, a left fork of the road goes about a mile and a half to Green River Overlook, which provides a superb view of Stillwater Canyon of the Green River, the Orange Cliffs beyond, and the Henry Mountains in the extreme distance (fig. 23). Note that here the White Rim Sandstone is much thicker than in preceding views. The prominent butte enclosed by the loop of the river is known as Turks Head and is better seen from the air (fig. 24). The light-colored band near the base of the cliffs in the background of figure 24 is characteristic of the bleached upper part of the Moenkopi Formation in this part of the park. According to F. A. McKeown and P. P. Orkild (U.S. Geol. Survey, unpub. data, Feb. 16, 1973), petroliferous material or odor generally occurs in this bleached zone and in the basal beds of the Moenkopi.

The campground just north of Green River Overlook has no water at this writing (1973), but water from wells in Taylor Canyon will eventually be piped to nearby parts of Island in the Sky.

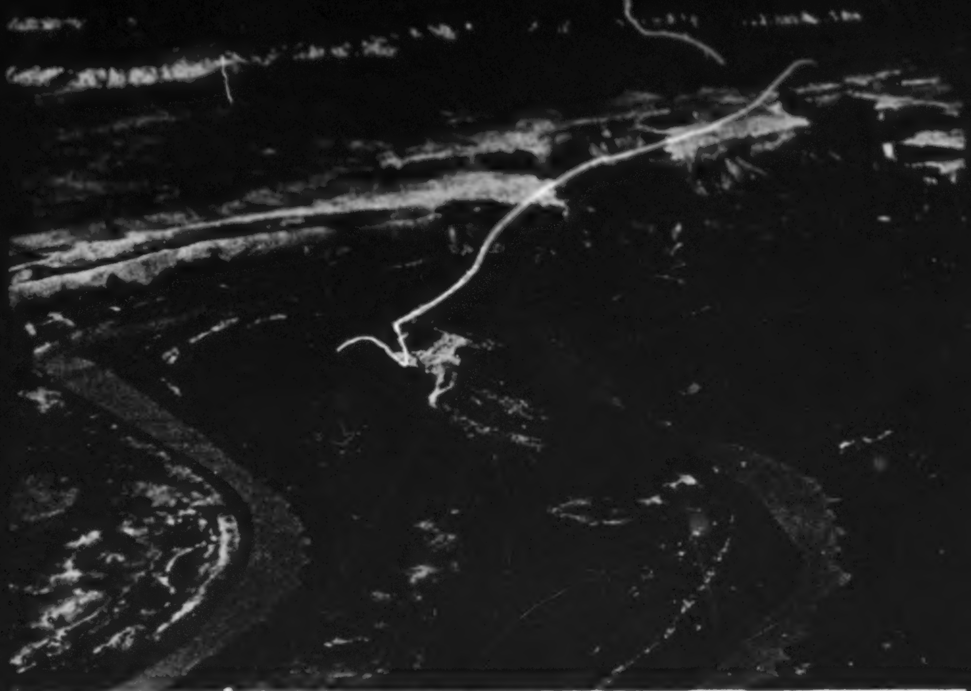
UPHEAVAL DOME

Five miles northwest of the Y we come to Upheaval Dome, one of the most unusual geographic and geologic features of the park. Viewed from the air (fig. 25), it resembles somewhat a volcanic or meteor crater and has been called such by some. Because beds of salt are known to underlie the park, some have suggested that the salt may have thickened and welled upward to form a salt dome, similar to domes along the Gulf Coast (Mattox, 1968). However, only 1,470 feet of salt was encountered in an oil test just east of Upheaval Dome (Robert J. Hite, U.S. Geol. Survey, oral commun., Feb. 13, 1973); so although salt may have played a role, Upheaval Dome clearly is not a salt dome with dimensions similar to the Gulf Coast types. It may be related to a mound on the deep-seated Precambrian rocks (Joesting and Plouff, 1958, fig. 3; Joesting and others, 1966, p. 13, 14, 17), but the exact origin of the dome is not clear.

The central part has the structure of a dome, in that the strata dip downward away from the middle. A ringlike syncline, or downward fold in the rock layers (fig. 26), surrounds the dome, beyond which the strata resume their nearly flat position. The white rock in the bottom of the craterlike depression is not salt, but jumbled large fragments of the White Rim Sandstone. Surrounding that are slopes of the Moenkopi and Chinle Formations, cliffs of the Wingate Sandstone, a circular bench of the

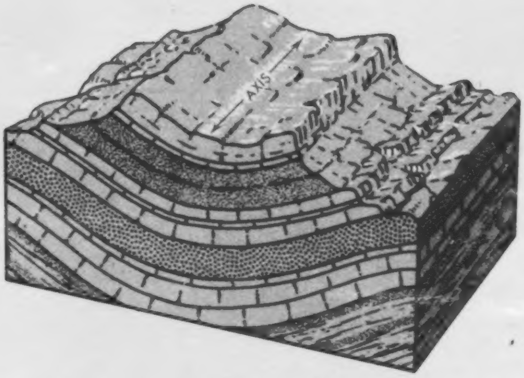


STILLWATER CANYON AND GREEN RIVER, looking southwest from Green River loop of river. Brown material covering nearby parts of the White Rim is lower part of Overlook. Orange Cliffs in background, Henry Mountains on right skyline, Turks Head in Moenkopi Formation. (Fig. 23)



TURKS HEAD, an erosional remnant of the White Rim Sandstone supported by red beds of Organ Rock Tongue, in loop of Green River. Aerial view looking north. Photograph by National Park Service. (Fig. 24)

UPHEAVAL DOME, aerial view looking northwest toward junction of Upheaval and Taylor Canyons with Labyrinth Canyon of Green River. Photograph by Walter Meayers Edwards, © 1971 National Geographic Society. (Fig. 25)



CUTAWAY VIEW OF SYNCLINE, or downfold of the rocks. From Hansen (1969, p. 108). (Fig. 26)

Kayenta Formation, and outer ramparts of the Navajo Sandstone. Upheaval Canyon leads to Stillwater Canyon of the Green River at the upper left.

One mile before the road ends, a well-marked foot trail leads to the top of Whale Rock, a prominence on the Navajo Sandstone that forms the outer ring of the dome. At the end of the road, another foot trail ascends from the picnic area to the foot of the Wingate Sandstone cliffs around the central part of the dome. The views of the dome from these trails are interesting, but you are really too close to get a true picture of the unusual feature, which is obtainable only from the air, as shown in figure 25.

Just west of Upheaval Dome, Bighorn Mesa is connected to Steer Mesa by a neck only 15 feet wide flanked by 300-foot vertical cliffs, as pointed out by McKnight (1940, p. 12). I later learned from Ed McKnight (oral commun., June 6, 1973) that during his field work in this area in 1926 he was riding a mule across this narrow neck when the half-asleep mule suddenly became aware of the dropoff on one side and began to turn around and head back. Ed hastily but cautiously dismounted and led the mule across! When this neck is finally breached by erosion, Bighorn Mesa will be just as isolated and inaccessible as Junction Butte, now cut off from Grand View Point. (See frontispiece and fig. 27.)

Hatch Point

The high mesa east of Canyonlands National Park and the Colorado River canyons, called Hatch Point, contains several vantage points ideally suited for viewing scenic features of the park and adjacent areas. Hatch Point is part of the vast public domain administered by the Bureau of Land Management—a sister agency of the Geological Survey and the National Park Service, all in the U.S. Department of the Interior. The Bureau, hereinafter referred to simply as the B.L.M., has made many improvements on Hatch Point, including fine roads, two modern campgrounds with sanitary facilities and piped water from wells, and two overlooks with protective fences, benches, paths, sanitary facilities, and ramadas containing panels that describe the features visible from the viewpoints. Because of these improvements, the B.L.M. has appropriately named this area "Canyon Rims Recreation Area."

Geologically, Hatch Point is similar to Island in the Sky. Both are bordered by towering cliffs of the Wingate Sandstone capped by the resistant Kayenta Formation, and rounded remnants of the overlying Navajo Sandstone rise above the otherwise-flat mesa surface in many places.

Access to this high tableland is by a good paved road leading west from U.S. Highway 163 at a point 32 miles south of Moab and 22 miles north of Monticello. About 5 miles west of the highway we pass Windwhistle Campground, nestled in an attractive cove of Entrada Sandstone cliffs, and 16 miles from the highway we reach an intersection. From here it is 7 miles west by paved road to Needles Overlook, 10 miles north to Anticline Overlook. Like the other high mesas, Hatch Point contains peripheral areas of scattered piñon and juniper trees and large flat grasslands used for grazing. Grain tanks here and there store winter feed for the cattle.

NEEDLES OVERLOOK

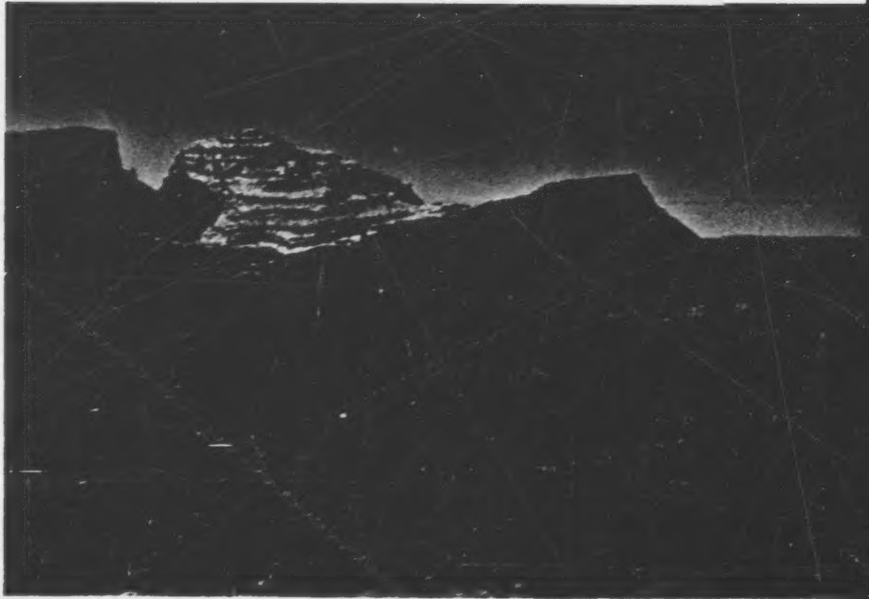
Let us follow the pavement to Needles Overlook, from which fine morning views of Canyonlands National Park can be seen to the south and west. Northwestward (fig. 27) we look 10 miles across the Colorado River canyon to Junction Butte and Grand View Point. (This view is along the line of the east half of the cross section in fig. 10.) The feather edge of the White Rim Sandstone caps the White Rim west of the Colorado River, but the White Rim is absent on the east side of the canyon and in the entire Needles district to the southwest, where the important scenic features are carved from the underlying Cedar Mesa Sandstone Member of the Cutler Formation, referred to hereinafter simply as the Cedar Mesa Sandstone. Both these sandstones are missing in the foreground of figure 27—their place being taken by thin beds of red siltstone, mudstone, and sandstone similar to those that comprise the Organ Rock Tongue shown between the two sandstones in figure 22. These are additional examples of facies changes mentioned earlier (p. 34).

JUNCTION BUTTE AND GRAND VIEW POINT, looking northwest from Needles Overlook. (Fig. 27)

CANYONLANDS OVERLOOK

Turning north from the intersection 7 miles east of Needles Overlook, we traverse a nearly flat grassy tableland to Hatch Point Campground. In figure 1 the campground is shown west of the old road; the new road is west of the campground, but no map of the new route was available for plotting in figure 1. About a mile before we reach the campground a jeep trail heads west then northwest about 5½ miles to Canyonlands Overlook, a scant mile from, but some 1,400 feet above, the eastern border of Canyonlands National Park. This overlook affords fine views of the Colorado River canyons and the eastern shore of Island in the Sky, but at present (1973) there are no plans to improve the trail for passenger-car travel.

Two miles north of the campground we cross a minor drainage leading northeastward into the north fork of Trough Springs Canyon. The B.L.M. plans a road down this canyon to Kane Springs Canyon, 1,100 feet below, where it will connect both with a scenic drive to Moab, the lower part of which is paved, and with the jeep trail going west over Hurrah Pass (fig. 30) and thence south along the eastern benches of the canyons of the Colorado River to the Needles district of the park. E. Neal Hinrichs (U.S. Geol. Survey, oral commun. Feb. 16, 1973) reported specimens of blue celestite (strontium sulfate, $SrSO_4$) and barite (barium sulfate, $BaSO_4$) in the Cutler Formation at a point where a sharp bend of this jeep trail crosses a fault, or fracture (fig. 56), in the northeast fork of Lockhart Canyon (shown in fig. 1 as the easternmost loop of the trail about 6 miles northeast of Lockhart Basin). Farther south, the trail swings west of Lockhart Basin, whose center exposes part of a syncline (fig. 28).



SYNCLINE IN CORE OF LOCKHART BASIN, near Needles Overlook. Dish-shaped roof is Wingate Sandstone, partly bleached; sloping sides are Chinle Formation; dark sloping ledge at left middle ground is Moss Back Member of Chinle resting on Moenkopi Formation. Photograph by E. N. Hinrichs. (Fig. 28)

U-3 LOOP

Two and a half miles farther north, or about 2 miles south of Anticline Overlook, a short road leads to the west and entirely around a small conical butte of the Navajo Sandstone. This new circular drive has not yet been formally named and is simply called the U-3 loop, as designated in the surveyor's notebook. It affords splendid views to the west and is to be equipped with picnic tables. Looking west (fig. 29) we see a W-shaped loop of the Colorado River, Dead Horse Point on the right skyline, and Island in the Sky on the distant skyline. The strata curving over Shafer dome appear in the right middle background.

VIEW WESTWARD FROM U-3 LOOP. Dead Horse Point on right skyline, Island in the Sky capped by Navajo Sandstone in extreme distance, Kayenta Formation in foreground at left. Cliffs topping ridge at left are Wingate Sandstone protected by caprock of the Kayenta Formation; red slopes beneath cliffs are Chinle Formation, with dark ledge of Moss Back Member at base; steep slopes and ledges beneath are Moenkopi Formation, lower part of which is Hoskinnini Tongue; reddish gentle slopes below are Cutler Formation; nearly flat benches above Colorado River are Rico Formation, with Shafer limestone at top. (Fig. 29)

ANTICLINE OVERLOOK

Two more miles takes us to Anticline Overlook for the most sublime views in this part of the area. To the north (fig. 30) we look across the northeast flank of the Cane Creek anticline, an upfold of the rocks (figs. 13, 14). Hurrah Pass straddles the narrow wall separating the Colorado River and its canyon at the left from Kane Springs Canyon on the right. The Colorado River appears again in the right background, where it leaves Moab Valley. The Kings Bottom syncline, or downfold (fig. 26), seen in the middle distance between the Cane Creek anticline and the Moab anticline, exposes a wide area of the Navajo Sandstone. The ridge on the right skyline, composed of the Entrada Sandstone, is The Windows Section of Arches National Park, and the left skyline shows faintly the distant Book Cliffs.

On the east wall of Kane Springs Canyon just to the right of figure 30 is the Atomic King mine in the Cutler Formation, from which uranium ore has been mined at intervals during the last 2 or 3 years.

LOOKING NORTH FROM ANTICLINE OVERLOOK, across axis of Cane Creek anticline. ▷ Unimproved road crosses Hurrah Pass in foreground. Colorado River at left is near Potash and in right background is at Moab. For description of strata, see caption for figure 31. (Fig. 30)

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To the northwest (fig. 31; see also fig. 13) is a textbook example of a rock fold—the Cane Creek anticline—laid bare by the Colorado River cutting directly across its crest (fig. 1). Anticlines are noted as sources of or at least hunting grounds for oil and gas, and this one is no exception, although production has been relatively small and was stopped altogether in about 1963. Some oil and gas was produced also from wells on the north flank of Shafer dome, just beneath Dead Horse Point (figs. 1, 15), but other favorable-looking structures farther south that were tested, such as Lockhart anticline, Rustler dome, and Gibson dome (fig. 1), failed to yield commercial amounts (Baker, 1933, p. 80-84). Some of the colorful events in the early days of wildcatting are noted on page 100.

Exploration for oil and gas led to the discovery of potash beneath several anticlines in eastern Utah and western Colorado. According to Hite (1968, p. 325), the Cane Creek anticline is underlain by about 5,200 feet of salt-bearing rocks in the Paradox Member of the Hermosa Formation (fig. 9), of which about 84 percent is halite (common salt, sodium chloride) and associated potash salts (sylvite, potassium chloride). The potash mine of Texas Gulf, Inc., is shown at the right in figure 31 The white area to the left of the mine is waste common salt, which is recovered with the potash salts, and the white area with dark stripes at the left is a small part of more than 400 acres of evaporation ponds built to separate the salts. These ponds also can be seen from Dead Horse Point. The dark stripes are the visible parts of plastic membranes lining the ponds. Mining of an 11-foot bed of ore began by usual underground methods from the bottom of a shaft 2,788 feet deep but became too difficult because of intense and intricate folding of the salt beds. Now the salts are being extracted by a method involving solution, wherein river water is introduced into the former workings and allowed to stand long enough to dissolve the salts, then the brine is pumped out to evaporation ponds, and the valuable potash salts are separated from the sodium salts. Closeup views of the mine and evaporation ponds are seen in figures 70 and 71.

◁ **CANE CREEK ANTICLINE**, looking northwest from Anticline Overlook. Colorado River is cutting into limestone of unnamed upper member of Hermosa Formation in lower bench at crest of fold; Rico Formation, with bluish-white Shafer limestone at top, forms upper curved bench; remainder of formations are as given in caption for figure 29. Potash mine (right) and evaporation ponds (left) are operated by Texas Gulf, Inc. Merrimac and Monitor Buttes on right skyline are shown in figure 12. (Fig. 31)

As noted earlier, most of the readily recognizable thin beds, such as the White Rim Sandstone, pinch out south of here, and figure 31 marks the northeasternmost exposure of the Shafer limestone at the top of the Rico Formation. Northeast from here the Rico and overlying Cutler Formation are not readily separable and are included in the so-called Cutler Formation undifferentiated. This land-laid unit of red sandstone, siltstone, and shale is as much as 8,000 feet thick just southwest of the ancient Uncompahgre highland (present Uncompahgre Plateau, in western Colorado and eastern Utah), from which it was derived by erosion during the Permian Period (fig. 80).

Orange Cliffs

The high mesas west of Canyonlands National Park do not form as distinct a mainland as does Hatch Point, but rather are broken up into a maze of peninsulas and islands, as shown in figure 1. Owing to the gentle northwestward dip of the rock strata, the altitude of the mesas declines from about 7,000 feet in the south to about 5,300 feet in the north and northwest, where the whole aspect of the country becomes more rounded and subdued. As shown on the map (fig. 1), however, the name Orange Cliffs is applied to much of the eastward-facing cliffs, which are made of the Wingate Sandstone capped by the Kayenta Formation. Remnants of the Navajo Sandstone increase in number to the north and west, where remnants of the next two younger rock units—the Carmel Formation and the Entrada Sandstone—also occur. Thus, the cliff-forming units dip downward beneath younger rocks that form the relatively flat Green River Desert to the northwest, also referred to as the San Rafael Desert. Figure 32 is a view southeastward from The Spur, shown on the map (fig. 1) as the northern section of the Orange Cliffs.

At present (1973), the areas west of the Green River and the main stem of the Colorado River are the least accessible of any in the park and in this respect have not changed much since Butch Cassidy and his Wild Bunch roamed the area, except that the former main horse trails are now jeep trails. A secondary road south from the town of Green River goes past the north side of the Horseshoe Canyon Detached Unit (figs. 1, 2) and connects with another secondary road to the west, which joins Utah

VIEW SOUTHEASTWARD FROM THE SPUR, in northern section of Orange Cliffs. Junction Butte and Grand View Point on left skyline; Abajo Mountains in extreme distance to right of center. Photograph by Parker Hamilton, Flagstaff, Ariz. (Fig. 32) ▷

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LOOKING NORTH DOWN MILLARD CANYON from head of canyon a mile northwest of French Spring. Note small arch or window in the Navajo Sandstone at upper left, which is shown in figure 1 as "Arch." The Navajo is underlain by the cliff-forming Kayenta Formation and Wingate Sandstone resting upon a sloping base of the Chinle Formation and, farther downstream, ledges and slopes of the Moenkopi Formation. Photograph by Parker Hamilton, Flagstaff, Ariz. (Fig. 33)

Highway 24 at Temple Junction, 20 miles north of Hanksville; near Horseshoe Canyon a jeep trail leads south to the Orange Cliffs. Owing to blowing sand, these "roads" are not considered reliable for passenger cars and are best negotiated by four-wheel-drive vehicles or horses.

According to Baker (1971, p. 12), the road leading eastward along North Point was used by the Wild Bunch in traveling to French Spring, whence they dropped down Millard Canyon (fig. 33) and crossed the Green River at Bonita Bend, which is just east of Buttes of the Cross (fig. 64). They also followed the Old Spanish Trail from the Henry Mountains eastward across the Dirty Devil River, up North Hatch Canyon, across Sunset Pass, and down across the Land of Standing Rocks to Spanish Bottom on the Colorado River (fig. 1). After crossing the river, they followed the trail up Lower Red Lake Canyon (fig. 59) and eastward through The Needles to Monticello.

The Benchlands

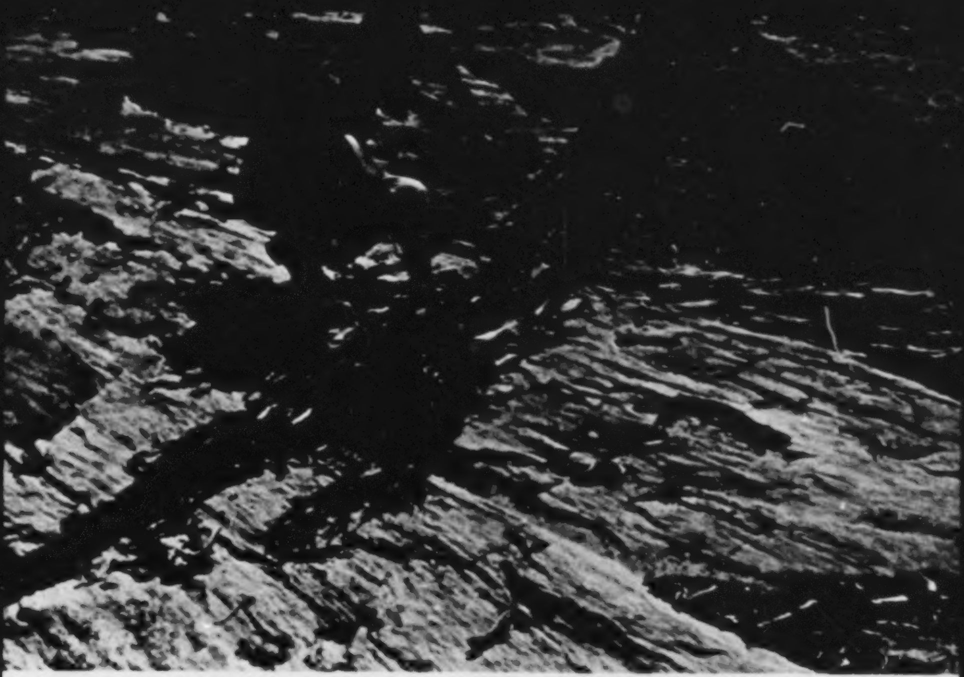
The White Rim, a broad benchland some 1,000-1,200 feet below the southern half of Island in the Sky, and some of the associated benchlands west of the Green River and between the Colorado River and Hatch Point have already been discussed as viewed from Island in the Sky, the White Rim Trail, or Hatch Point. There remain for consideration several other prominent benchlands.

The Maze and Land of Standing Rocks

The Maze, an intricately carved series of canyons and gullies, has been called a "Thirty-square-mile puzzle in sandstone" (Findley, 1971, p. 71-73), and one can readily visualize a king-sized rat struggling in vain to find a way out. The rock is the Cedar Mesa Sandstone, which here underlies red shales beneath the White Rim Sandstone. South of The Maze an area containing tall spires was appropriately named by the Indians *"Toom'-pin wu-near' Tu-weap',"* or "Land of Standing Rocks" (Powell, 1875, p. 154).

West of The Maze is Elaterite Basin, so named because of a dark-brown elastic mineral resin called elaterite, which seeps from the White Rim Sandstone. One of these seeps is shown in figure 34, and a wedge-shaped layer of the sandstone is shown in figure 35. In the Range Canyon area shown in figure 35, sand was being laid down in an offshore bar at the left, while red silts and muds were being deposited on land to the right. The dark bed just above the White Rim near the middle of the photograph is the Hoskinnini Tongue of the Moenkopi Formation, which intertongues with and pinches out in beds of the Moenkopi Formation to left. These are excellent examples of what geologists call facies changes.

South of the Land of Standing Rocks are equally colorful areas known as The Fins and Ernies Country (named after Ernie Larson, an early-day sheep man). A prominent row of spires near Cataract Canyon is known as The Doll House (fig. 36).



ELATERITE SEEPING FROM WHITE RIM SANDSTONE in Elaterite Basin west of The Maze. Elaterite is a dark-brown elastic mineral resin. Photograph by Donald L. Baars. (Fig. 34)

WHITE RIM SANDSTONE in north wall of Range Canyon, south of Elaterite Basin. Bed thins from 230 feet at left (west) to 38 feet at right (east), and disappears (by facies change into red shales) a short distance farther east. See description in text of pinch out of Hoskinnini Tongue. Bed at top of mesa is Moss Back Member of Chinle Formation. Photograph by Donald L. Baars. (Fig. 35)

THE DOLL HOUSE, eroded from Cedar Mesa Sandstone just west of Spanish Bottom, above Cataract Canyon. Notice the red layer at right offset by a fault. Photograph by Parker Hamilton, Flagstaff, Ariz. (Fig. 36)

The Needles district

The Needles district is currently (1973) the most highly developed part of the unfinished park as the result of design, not accident, for this district includes the greatest number and widest variety of spectacular features—The Needles proper, The Grabens (pronounced gräbəns), colossal arches and other erosional forms, large meadows such as Squaw Flat and Chesler and Virginia Parks, a wide variety of prehistoric ruins and pictographs, and Confluence Overlook for viewing the joining of two mighty rivers—the Green and the Colorado. Like the White Rim and The Maze, the Needles district is another of the broad benchlands about midway between the high mesas and the deep canyons.

Utah Highway 211, as mentioned already, is a 38-mile-long paved road leading to the Needles district from U.S. Highway 163 at a point 15 miles north of Monticello and 18 miles south of La Sal Junction. The intersection is well marked by Church Rock (fig. 37), a butte of the Entrada Sandstone. Highway 211 gradually climbs an eastward-dipping slope of the Navajo Sandstone dotted with a few buttes and patches of the Entrada Sandstone, such as Church Rock, and reaches the first of two summits 3 miles west of Highway 163. The road crosses a broad gentle valley in the Navajo Sandstone, reaches the second summit about 10 miles from the highway, then descends steeply through the Navajo Sandstone and part of the Kayenta Formation to Indian Creek, 1½ miles below, and follows this creek nearly to The Needles. Half a mile down the canyon takes us to the top of the cliff-forming Wingate Sandstone, and another half mile brings us to Indian Creek State Park and its striking Newspaper Rock (fig. 5). Another 1¾ miles takes us to the base of the Wingate and top of the underlying Chinle Formation, which forms the red slope beneath the cliffs.

Historic Dugout Ranch (p. 14) is 19 miles west of the highway, and from here a dry-weather road leads southward up north Cottonwood Creek 37 miles to Beef Basin and connects with roads to Elk Ridge and the Bears Ears, both just west of the Abajo Mountains. Just west of the ranch we get a good view ahead of two historic landmarks—North and South Six-Shooter Peaks (fig. 38), so named because of their resemblance to a pair of revolvers pointing skyward. The guns are sculptured from slivers of Wingate Sandstone resting upon conical mounds of the Chinle. These can be seen from a wide area; both appear in figures 38 and 40, and the north one is seen in figure 77.

CHURCH ROCK, standing guard at the intersection of U.S. Highway 163 and the east end of Utah Highway 211 leading to the Needles district. Rock is Entrada Sandstone: red foundation is Dewey Bridge Member; yellowish smooth rounded body of church is Slick Rock Member; white steeple is Moab Member. La Sal Mountains at left. (Fig. 37)

NORTH AND SOUTH SIX-SHOOTER PEAKS, looking west from entrance road to The Needles. (Fig. 38)

A mile west of Dugout Ranch we descend to the top of the Moss Back Member of the Chinle, a ledge of gray-green sandstone forming the base of this generally red formation, and reach the base of the member at the top of the Moenkopi Formation in the next mile and a half. The Moss Back is uranium bearing in nearby areas.

At 3.8 miles west of Dugout Ranch a poorly marked road on the left crosses Indian Creek, then forks; the left-hand fork follows the bed of Lavender Canyon, and the right-hand fork goes into Davis Canyon. Headwaters of both these canyons are new additions to the park.

The red Organ Rock Tongue of the Cutler Formation is seen about 3 miles beyond the turnoff, or about 6 miles west of Dugout Ranch. Another 1½ miles takes us down in the rock column (fig. 9) to the top of the Cedar Mesa Sandstone. The White Rim Sandstone, which forms such a prominent bench around the southern part of Island in the Sky (figs. 20-23) and west of the Green River, is missing from the Needles district, its place in the rock column being taken by red shales and sandstones of the Cutler Formation. South of Indian Creek other underlying red beds of the Cutler are gradually replaced in turn by the thick Cedar Mesa Sandstone. Erosion has reduced the general level of the Needles district to or into the Cedar Mesa Sandstone, but many streams have cut into the underlying Rico Formation, and the Colorado River has cut also into, and in places through, the limestones of the unnamed upper member of the Hermosa Formation. Our first view of The Needles is another 4 miles, and 1 more mile takes us to the park boundary, nearly 32 miles from the U.S. Highway 163. We pass a road on the right leading to Canyonlands Resort, and on the left is a new line camp which replaces the restored one at Cave Spring (fig. 6).

The unusual features of the Needles district are due in some part to the character and thickness of the underlying rocks but in large part to erosion along joints and faults. Joints are fractures along which no displacement has taken place, and faults are fractures along which there has been displacement of the two sides relative to one another (fig. 76). The Cedar Mesa Sandstone comprises 500 to 600 feet or more of hard well-cemented buff, white, and pink beds of massive sandstone. On the basis of the type and amount of deformation and erosion of the Cedar Mesa Sandstone and underlying rocks, the Needles district can be divided into three differing areas: (1) an eastern area where the rocks are relatively undeformed but are carved into an intricate series of canyons, including Salt Canyon and the upper reaches of Davis and Lavender Canyons—the section of the district that contains most of the arches and Indian ruins; (2) The Needles proper, where tensional forces have cracked the brittle Cedar Mesa Sandstone into a crazy-quilt pattern of square to rectangular blocks separated by joints widened by erosion, creating a myriad of spires and pinnacles; and (3) The Grabens, where the previously jointed rocks were later subjected to additional tensional forces that produced a series of nearly parallel faults that trend northeastward and separate downdropped blocks of rock, called grabens, from intervening stationary or upthrown blocks of rock, called horsts.

Let us examine each of these areas in the order named. For traveling to most features a four-wheel-drive vehicle is strongly recommended. Some visitors negotiate the jeep trails with dune buggies or motorcycles, but four-wheel-drive vehicles are considered safer and generally more reliable. A few trails can be traveled only on foot.

Squaw Flat, in the western part of the relatively undeformed area, is a nearly flat area of lower Cedar Mesa Sandstone covered here and there by a thin layer of sparsely vegetated soil and surrounded by generally low hilly erosional forms in the upper part of the sandstone. Short canyons and alcoves in the

SQUAW FLAT CAMPGROUND, in the Needles district, in Cedar Mesa Sandstone. Large pinon and juniper trees draw ground water from this sandstone. (Fig. 39)

sandstone hills along the west side afford excellent semi-private campsites, each of which has its own paved access road, picnic table, and trash can (fig. 39). Moreover, ground water at shallow depth in the underlying sandstone has encouraged the growth of exceptionally large piñon and juniper trees that provide welcome shade.

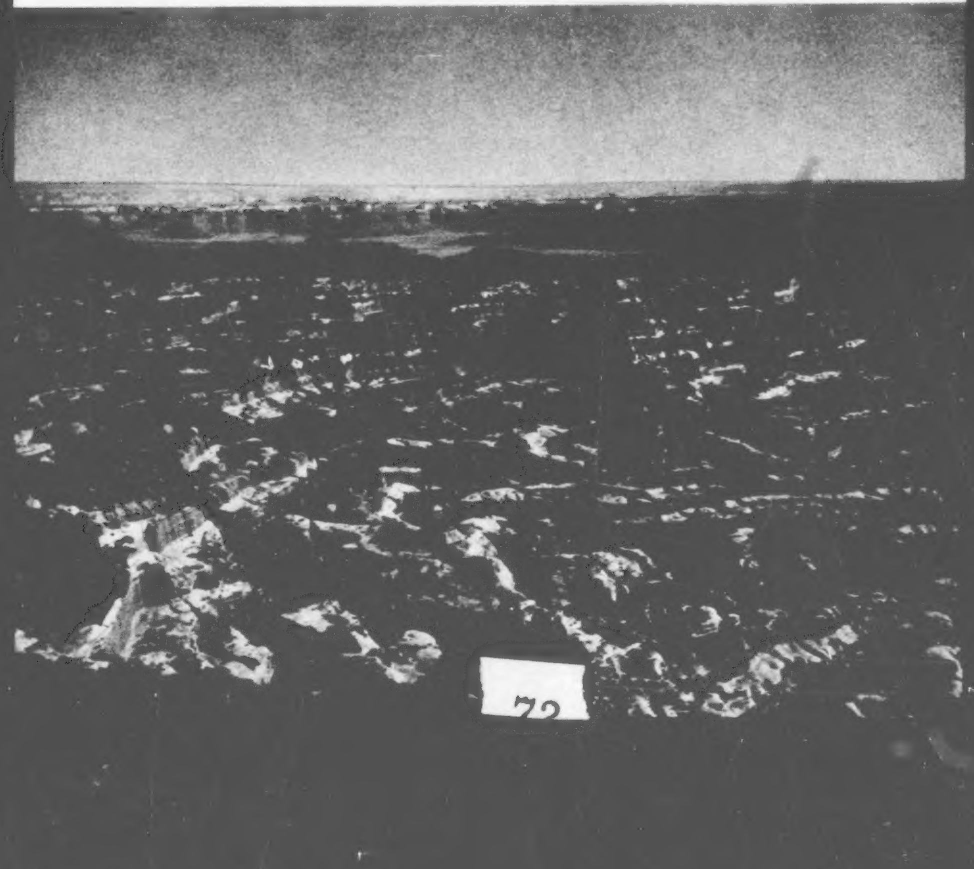
SALT, DAVIS, AND LAVENDER CANYONS

A glance at the southeast corner of the map (fig. 1) shows that most of the arches and prehistoric ruins in the park are in Salt Canyon and its main tributary, Horse Canyon. A few are in adjacent Davis and Lavender Canyons, whose headwaters were recently annexed to the park. These canyons are accessible only by negotiating the streambeds on four-wheel-drive vehicles, horseback, or foot. Salt or Horse Canyons are best conquered by four-wheel-drive vehicles plus short hikes in the northern part and long hikes in the southern part.

An aerial view (fig. 40) eastward across Salt Canyon shows that erosion has produced an intricate series of meandering canyons separated by rather narrow walls of the Cedar Mesa Sandstone, resembling somewhat The Maze, west of the Green River.

The massive sandstone beds of the Cedar Mesa are composed of sand grains cemented together by calcium carbonate ($CaCO_3$), which also forms the mineral called calcite and the rock known as limestone. Limestone and calcite are soluble in acid, even weak acid such as carbonic acid ($H \cdot HCO_3$), formed by solution of carbon dioxide (CO_2) in water. Ground water, found everywhere in rock openings at differing depths beneath the surface, contains considerable dissolved carbon dioxide derived from decaying organic matter in soil, from the atmosphere, and from other sources. Even rain water and snow contain small amounts absorbed from the atmosphere—enough to dissolve small amounts of limestone or of calcite cement in sandstone. The calcite cement in the Cedar Mesa and many other sandstones is unevenly distributed, so the cement is removed first from places that contain the least amounts, and once the cement is dissolved, the loose sand grains are carried away by gravity, wind, or water. Thus, relatively thin walls of sandstone containing irregularly distributed patches of soluble cement are prime targets for the formation of potholes (fig. 46), alcoves, and caves. Once a breakthrough occurs, weakened chunks from the ceiling tend to fall off, and arches of various shapes are produced, because an

AERIAL VIEW EASTWARD ACROSS SALT CANYON. Note narrow walls and pinnacles between canyons and alcoves. Six-Shooter Peaks are in left background. Photograph by Wayne Alcorn, National Park Service. (Fig. 40)



arch is naturally the strongest form that can support the overlying rock load. Man, from the ancient Greeks, Romans, and Egyptians to modern day, has long made use of arches in building bridges, aqueducts, temples, cathedrals, and other enduring edifices. All the spectacular arches we are about to see were carved from the Cedar Mesa Sandstone.

Let us begin our tour of Salt and Horse Canyons by driving a four-wheel-drive vehicle eastward from the fine campground at Squaw Flat. After about a mile we pass the Wooden Shoe (fig. 41) capping a ridge south of the highway; it contains one of the smallest arches we will encounter. Three quarters of a mile east of the temporary ranger station we come to Cave Spring, an old restored cowboy line camp pictured in figure 6. This and an adjacent cave containing a spring are part of the interesting well-marked Environmental Trail, well worth the half hour or so it requires.

The jeep trail up Salt Canyon lies mostly in the sandy bed of Salt Creek but includes a few shortcuts across goosenecks and some rough rocky stretches around rapids or waterfalls. It is best traveled when the canyon bottom is moist but not soaked. When the sand is soft and dry, a shift into four-wheel drive is generally necessary. Signs warn of quicksand, which occurs when the sand is fully saturated; hence, summer thundershowers sometimes require delaying or postponing the trip.

WOODEN SHOE, near temporary ranger headquarters, the Needles district. Carved in Cedar Mesa Sandstone. (Fig. 41)

When in doubt, consult a park ranger for expected weather and trail conditions. Thundershowers sometimes occur so suddenly and violently as to cause serious floods, and the "road" is closed when heavy rain is expected. However, if an unexpected storm occurs while you are up in the canyon, try to reach high ground and wait until the flood subsides. If you do not have time to get your vehicle out of the flood's path, at least get yourself and passengers to a safe spot.

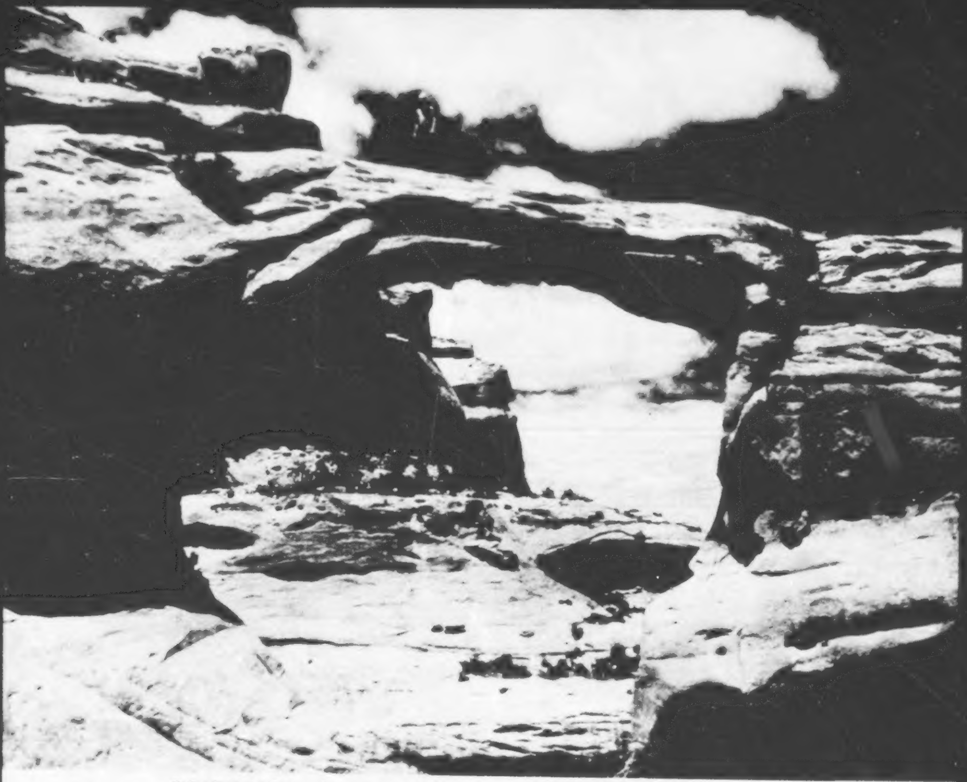
Two and a half miles south of Cave Spring we reach the confluence with Horse Canyon, marked by a sign at the Y giving distances to points of interest up each canyon. Let us try Horse Canyon first. After about a mile we pass Paul Bunyans Potty on the left—one of the most aptly titled features of the park (fig. 42). Two miles south of the Y is Keyhole Ruin, nestled in a cleft

PAUL BUNYANS POTTY, on east wall of Horse Canyon. (Fig. 42)

high on the cliff to our left—a granary built by the Anasazi. Here we face another Y. The left fork leads half a mile east to Tower Ruin (fig. 4), one of the largest and best preserved Anasazi granaries in the park. The right fork takes us on up Horse Canyon, and in about 2 miles we pass Gothic Arch on the right. In 2 more miles, 4 miles from Salt Canyon, a short hike up the tributary to the right leads to Castle Arch and Thirteen Faces. Assuming we have taken photographs of the important features along the way, it probably is about time to return to camp at Squaw Flat, unless we choose to spend the night at Peek-a-boo Spring and primitive campground in Salt Canyon, about 1.2 miles above the confluence with Horse Canyon.

Another drive takes us up Salt Canyon 8½ miles past the confluence with Horse Canyon to another confluence and Y, which has a primitive campsite without water. One mile up the left, or southeast, tributary is a parking area where we begin the ½-mile walk to Angel Arch, considered by many people to be the most beautiful and spectacular arch in the park if not in the entire canyon country. Angel Arch was drawn for the front cover by John R. Stacy and is pictured in figure 43.

ANGEL ARCH, along tributary of Salt Canyon. (Fig. 43) ▷

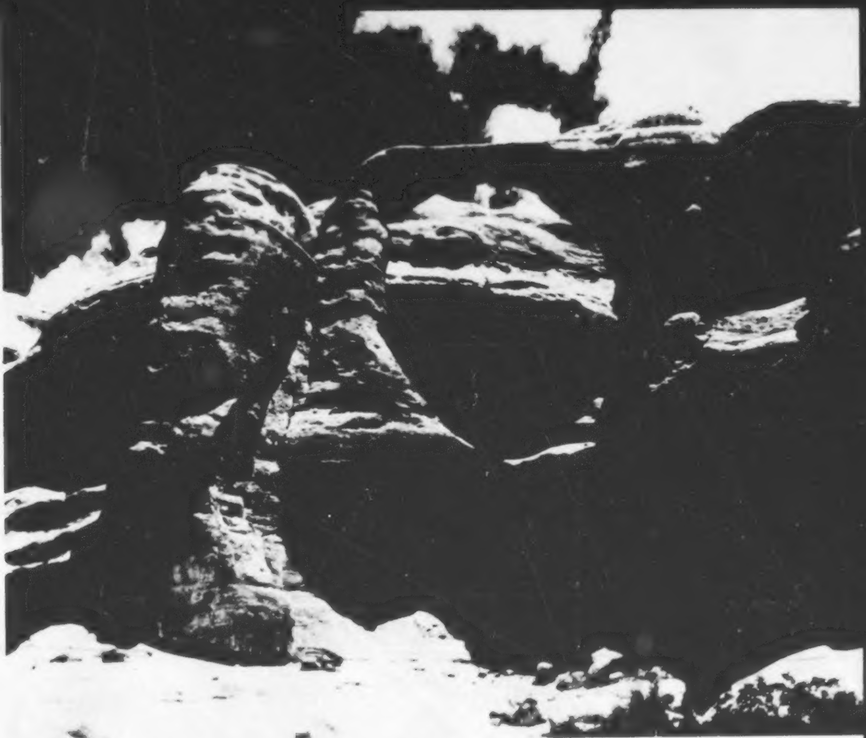


FISHEYE ARCH, along upper Salt Canyon, looking north. Photograph by National Park Service. (Fig. 44)

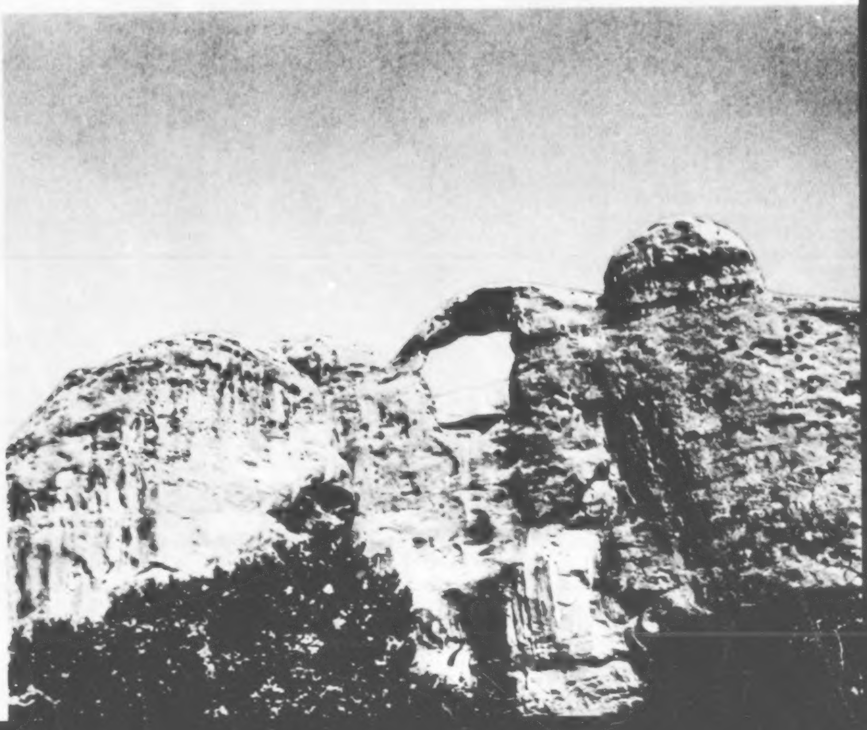
From the last Y we can proceed only about 2½ miles farther up main Salt Canyon by vehicle, and the remaining features shown on the map (fig. 1) can be reached only on foot. The All American Man, a unique pictograph referred to earlier (fig. 3), is about 3½ miles up the canyon. Those hardy souls who wish to hike many additional miles to the head of Salt Canyon will be rewarded with views of four additional arches and several ruins. Two of these arches are shown in figures 44 and 45.

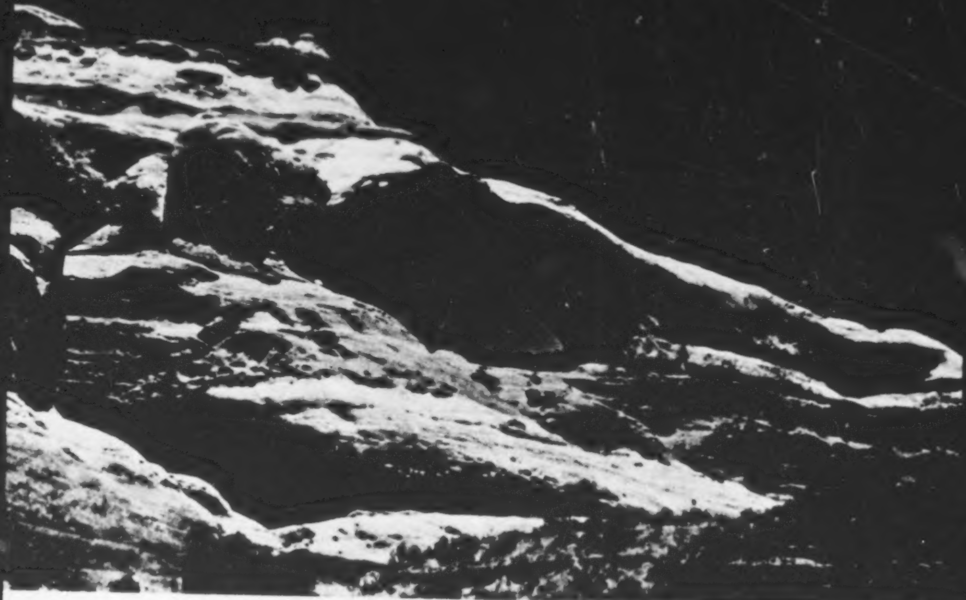
The more adventuresome may wish to explore upper Lavender and Davis Canyons by driving up the sand washes in a four-wheel-drive vehicle, but inquiry should be made from a park ranger regarding access to the canyon mouths and condition of the washes. Hand Holt Arch (fig. 46) and Cleft Arch (fig. 47) are two of the rewarding sights in Lavender Canyon, and figure 48 shows one of the arches in Davis Canon.

HAND HOLT ARCH, in Lavender Canyon. Note holes in sandstone formed by solution ▷ and wind scour. Photograph by National Park Service. (Fig. 46)



WEDDING RING ARCH, along upper Salt Canyon. Photograph by National Park Service.
(Fig. 45)





CLEFT ARCH, in upper Lavender Canyon, looking north. Photograph by E. N. Hinrichs. (Fig. 47)

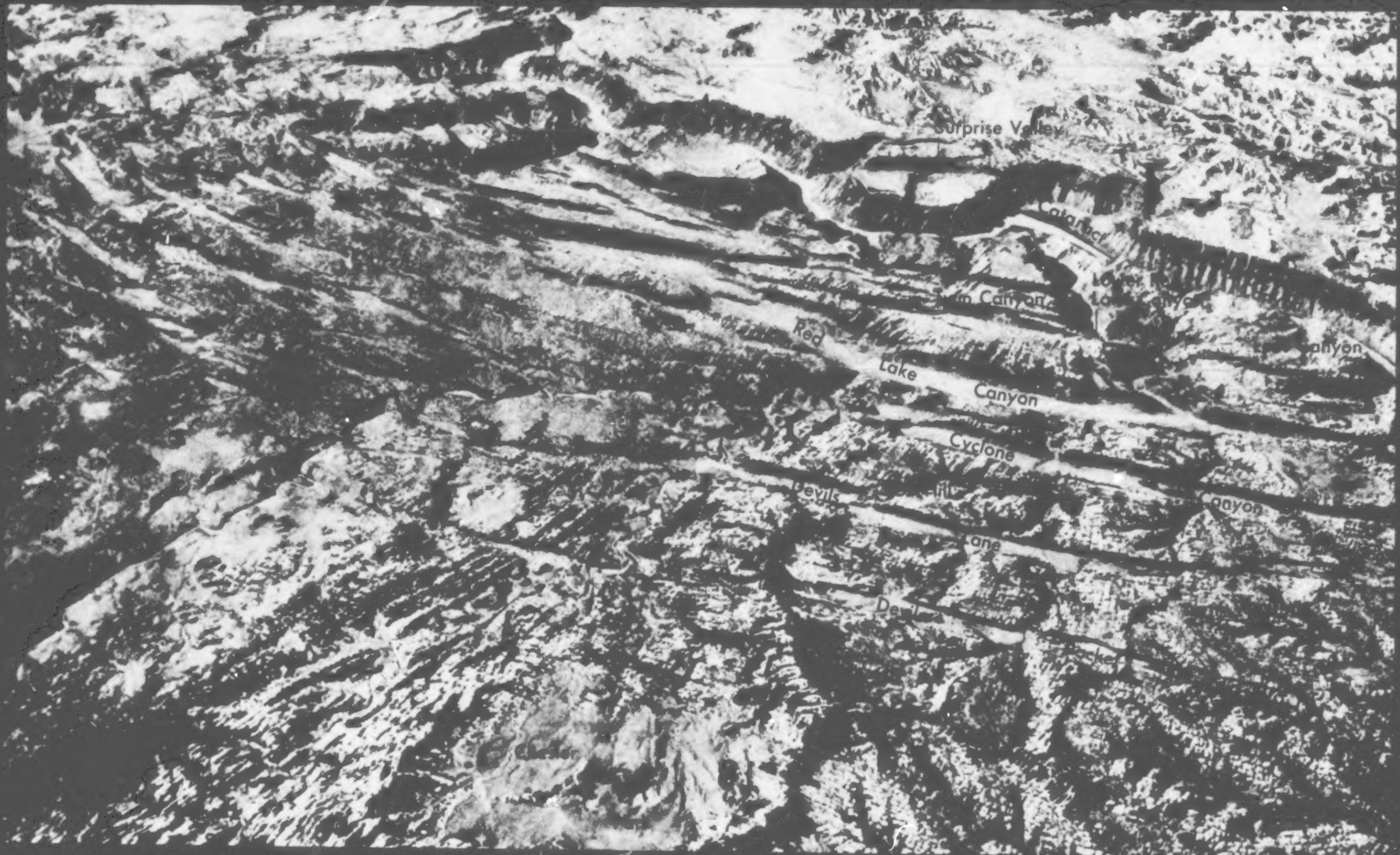
ARCH, in upper Davis Canyon, looking northwest. Photograph by E. N. Hinrichs. (Fig. 48)

THE NEEDLES AND THE GRABENS

The northeastern edge of The Needles proper can be seen from Squaw Flat (fig. 49), but the true character of The Needles can be appreciated better from the air (fig. 50). You cannot get far into The Needles without traversing part of The Grabens, so we will consider them together. An aerial oblique view (fig. 51) shows The Needles in the foreground and The Grabens in the middle background. As shown on the map (fig. 1), you can hike

THE NEEDLES, looking southwest from Squaw Flat. (Fig. 49)

CHESLER PARK IN THE NEEDLES, aerial view looking northeast. Photograph by Walter Meayers Edwards, © 1971 National Geographic Society. (Fig. 50)


Surprise Valley
Cataract
Lower
Lake Canyon
m Canyon
Canyon
Red
Lake
Canyon
Cyclone
Canyon
Devils
Lane
Devil
ocket
Chesler

into The Needles and The Grabens from Squaw Flat, but let us make the trip using a four-wheel-drive vehicle and several short hikes.

Ordinary passenger cars now can go 2¾ miles west of Squaw Flat to Soda Spring, at the east base of Elephant Hill, but beyond Soda Spring four-wheel-drive vehicles should be used. Some people conquer the hill in dune buggies or on motorcycles, but this is considered quite dangerous. Both sides of this short (1¼ miles) but formidable hill have switchback curves too sharp to negotiate in the regular manner, so special driving techniques must be followed. On the east side, you must drive out on a flat rock, jockey back and forth until turned completely around, then proceed up the hill. On the west side, you descend a 40-percent grade to a shelf, *back* down a narrow stretch of about 30-percent grade and back sharply to the left onto a flat rock, then go forward again. On the return trip the whole procedure is carried out in reverse order.

West of Elephant Hill, the road reaches a Y, at which you must turn left on a one-way road; the right-hand road is for later one-way return to the Y. Why the left-hand fork is one way soon becomes apparent, for the road leads into a narrow shallow graben, called Devils Pocket (fig. 51), between rock walls, and is barely wide enough for one car. After about 2 miles the graben widens out into a beautiful spot called the Devils Kitchen, which contains several picnic tables tucked into shady recesses in the sandstone walls. This is the starting point for two trails leading southward by different routes to Chesler Park, from which other trails lead to Druid Arch or back to Squaw Flat.

From the Devils Kitchen, the road turns abruptly westward for about half a mile to another Y in about the middle of Devils Lane, one of the larger grabens and one of two whose entire length is traversed by roads, as shown on the map (fig. 1). Only the left fork is a two-way road, so let us take the left fork 2¾ miles southwestward to the next road junction. About halfway down Devils Lane, a fault crossing the graben has created a narrow steep ridge appropriately called SOB Hill, because the road over it creates a challenge that some vehicles fail to meet on the first attempt!

The next road intersection is now shown on the map (fig. 1) as a sharp turn leading southwest to Ruin Park and Beef Basin. The abandoned left fork (not shown) leads east into Chesler

◁ **THE NEEDLES AND THE GRABENS,** aerial oblique view looking west over Chesler Park in foreground, The Grabens to the right, and Cataract Canyon behind. Photograph by U.S. Army Air Force. (Fig. 51)

Park. This park, shown in figure 50 and near the bottom of figure 51, is a beautiful natural meadow of several hundred acres fenced by a natural wall of needles and containing a central island of needles. Because of vehicular damage to meadow vegetation, the National Park Service found it necessary to close the road. To reach Chesler Park now, vehicles must go right a short distance to the Chesler Canyon turnoff, then left about half a mile to a parking area. From here, a ½-mile hike east through the narrow Joint Trail gets us to the south side of Chesler Park, where we join the abandoned road to reach the northeast corner of the park and the trails into The Needles proper (fig. 1).

This change adds 1¾ miles (one way) to the hike to Druid Arch, making the round trip about 11½ miles. At the old trailhead, near the northeast corner of Chesler Park, is a sign proclaiming the need for rubber-soled shoes and water, and I strongly support these admonitions, for much of the hike is on bare smooth sandstone and includes steep slopes and *generally* dry waterfalls. The hike should not be attempted by anyone not in good physical condition, and it should not be undertaken alone; two or more people should travel together.

As shown in figure 52, the trail to Druid Arch from Chesler Park starts out on bare Cedar Mesa Sandstone marked by a succession of rock cairns, two of which are visible and without which the trail would soon be lost. The trail drops rapidly down into Elephant Canyon, which is then followed southward 2 miles to the arch. This canyon has cut through the Cedar Mesa into the underlying Rico Formation, and much of the canyon is quite narrow and steep sided, as shown in figure 53. Although much of the Rico consists of red beds laid down above sea level by ancient streams, the trail crosses several thin beds of dark-gray hard limestone containing fossil marine seashells and ancient sea anemones whose original calcium carbonate parts have been locally replaced by jasper (red iron-bearing silica). When at last the weary hiker makes the steep climb out of the canyon and rounds the final bare-rock curve, the sudden and striking view of Druid Arch (fig. 54) seems worth every bit of the effort—at least it was to me and my hiking companion.

After my friend and I hiked to Druid Arch and after the length of this route was increased to a round-trip distance of 11½ miles, a new route was constructed having a round-trip length of only 8½ miles. This new trail starts at the end of the passenger-car road at the east edge of Elephant Hill, goes 1¼ miles southwest to join an older trail in Elephant Canyon, then follows this canyon 3 miles south to the arch.

TRAIL TO DRUID ARCH, near its beginning at northeast corner of Chesler Park, marked only by rock cairns, two of which are visible. (Fig. 52)

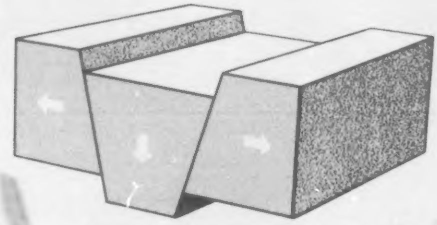
UPPER ELEPHANT CANYON, containing trail to Druid Arch. (Fig. 53)

After returning to our vehicle west of Chesler Park and backtracking over SOB Hill to the intersection in the middle of Devils Lane, let us proceed northward on a one-way road to and beyond the Silver Stairs for a closer look at Devils Lane and other grabens to the west and for a look at the confluence of the Green and Colorado Rivers. But first let us pause and reflect upon the possible origin of The Grabens.

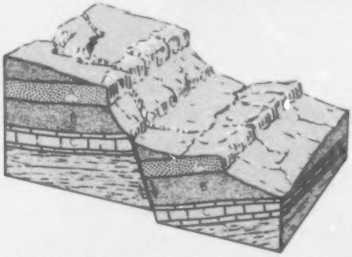
Geologists have different opinions as to just how grabens and complex systems of joints have formed, but all seem to agree that tensional forces were involved. Some think that solution of salt and gypsum from the Paradox Member of the Hermosa Formation by ground-water movement allowed the brittle Cedar Mesa Sandstone and other overlying rocks to sag, producing tension cracks and faults. Others believe that removal of the salt and gypsum occurred by plastic flowage toward the Meander anticline (see p. 108 and fig. 61), whose axis follows the Colorado River southwest from The Loop, past the confluence, and to and beyond Spanish Bottom. Some suppose that compaction due to the weight of the abnormally thick pile of sedimentary rock underlying the area may have caused the sagging, cracking, and faulting. The rock deformation may have resulted from a combination of these and possibly other things, of course, but whatever the cause, the resulting features are very striking. There was room to show only two of the named grabens within the park on the map (fig. 1), but all are shown in figure 51, and several appear in figure 59. A diagramatic cross section of a typical graben is shown in figure 55. The tension faults shown in figures 55 and 56 are called normal faults, in contrast to faults formed by horizontal compression, which are called reverse faults (figs. 75, 76).

The Grabens range in width from about 7 or 8 feet at the north end of Devils Pocket to nearly 2,000 feet at the south end of Red Lake Canyon, but the average width is about 500 feet. The floors of The Grabens are covered by soil and grass, but the displacement along the faults is believed to approximate the height of the walls—nearly 300 feet. That The Grabens are of fairly recent origin is attested by the fact that most of the walls are vertical fault faces showing little sign of erosion (fig. 57); that no through drainage has yet been established in Cyclone Canyon, which is a series of basins with low divides between; and that several pre-existing streams were interrupted or diverted by the faulting.

◁ **DRUID ARCH**, from end of arduous trail shown in figures 52 and 53. (Fig. 54)



A SIMPLE GRABEN, formed by tension in directions indicated by horizontal arrows. Downdropped central block is the graben; stationary or uplifted blocks on sides are called horsts. From Hansen (1969, p. 123). See also figure 76. (Fig. 55)



CUTAWAY VIEW OF NORMAL FAULT, resulting from tension in and lengthening of the earth's crust. Note amount of displacement and repetition of strata. Compare with figure 76. From Hansen (1969, p. 116). (Fig. 56)

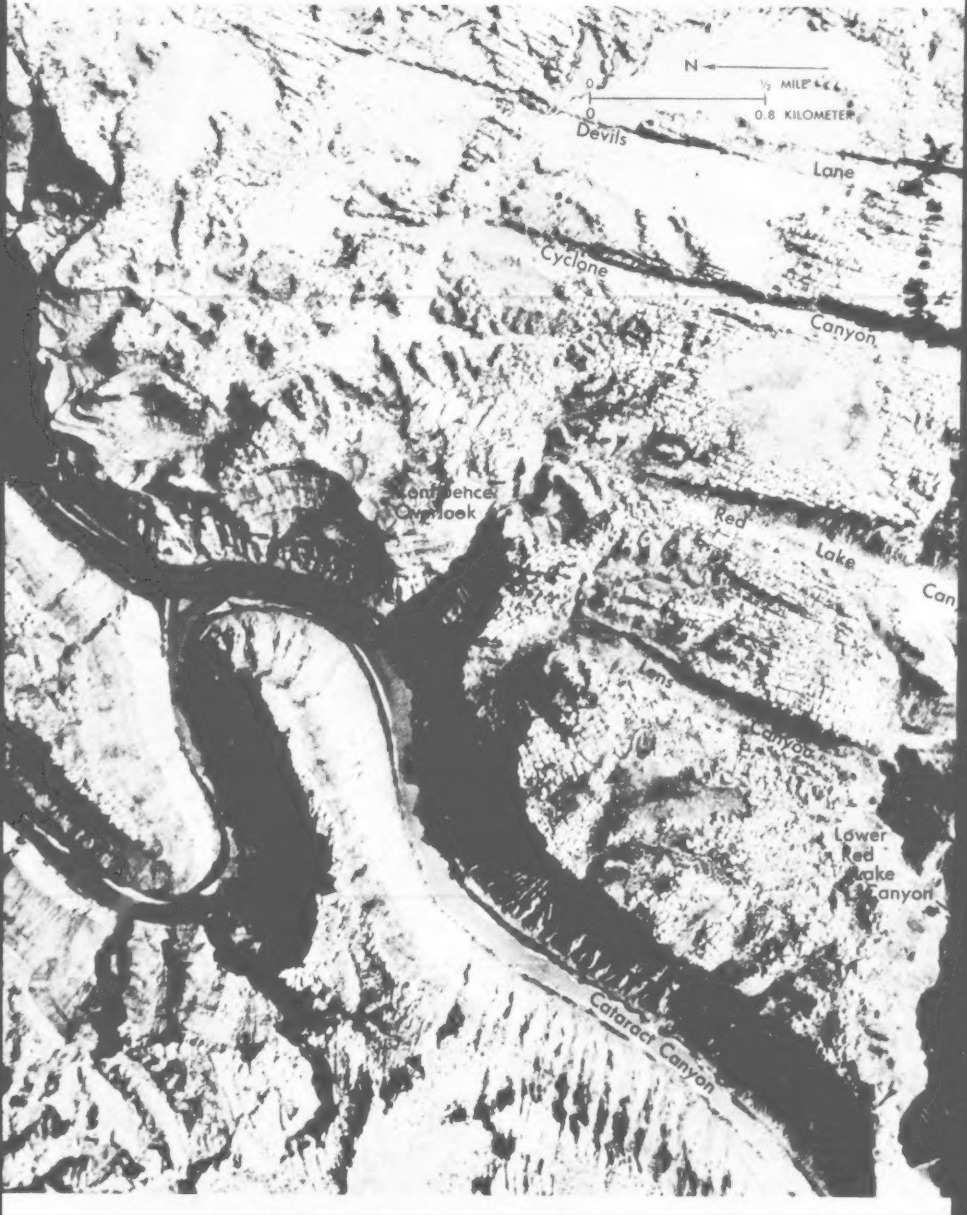
Now let us continue our journey northward along Devils Lane. Just before reaching the Silver Stairs we may wish to pause long enough to take in the distant view to the northwest toward Junction Butte and Grand View Point. (See frontispiece.) After descending the steep Silver Stairs in a narrow cleft between rock walls, we reach another intersection: a two-way road continuing northwest goes to our destination, and a one-way road turning right returns to Elephant Hill via part of Elephant Canyon (fig. 58).

About 2 miles to the northwest we cross the north end of Cyclone Canyon, the largest graben. It contains a road 3½ miles long and is well worth seeing. About one-half mile from the south end, an old trail follows Red Lake and Lower Red Lake Canyons to the Colorado River across from Spanish Bottom (figs. 1, 61).

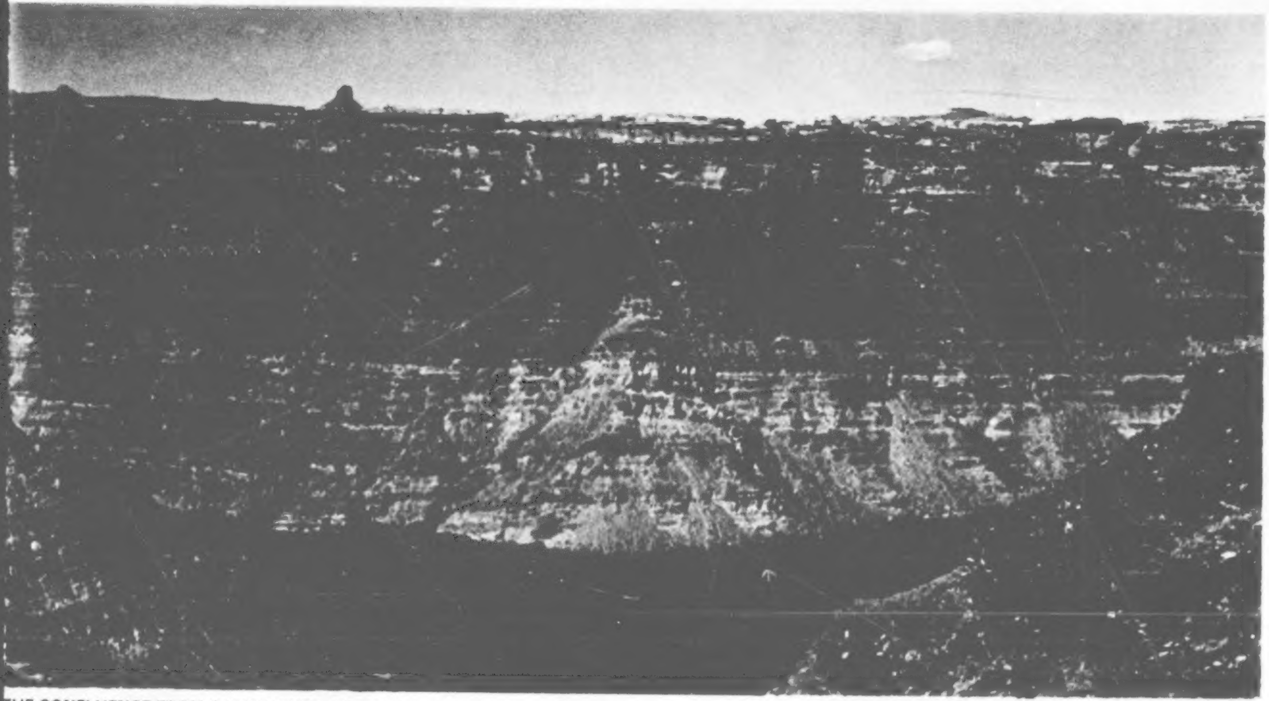
From near the north end of Cyclone Canyon (figs. 1, 59), we drive west three-fourths mile to a parking area and hike one-half mile to an overlook for a spectacular view of the confluence of the Green and Colorado Rivers (figs. 59, 60) and of the northern part of Cataract Canyon (fig. 61). These and other canyons are discussed in the next chapter.

WEST WALL OF CYCLONE CANYON GRABEN, a nearly vertical fault face showing little sign of erosion. (Fig. 57)

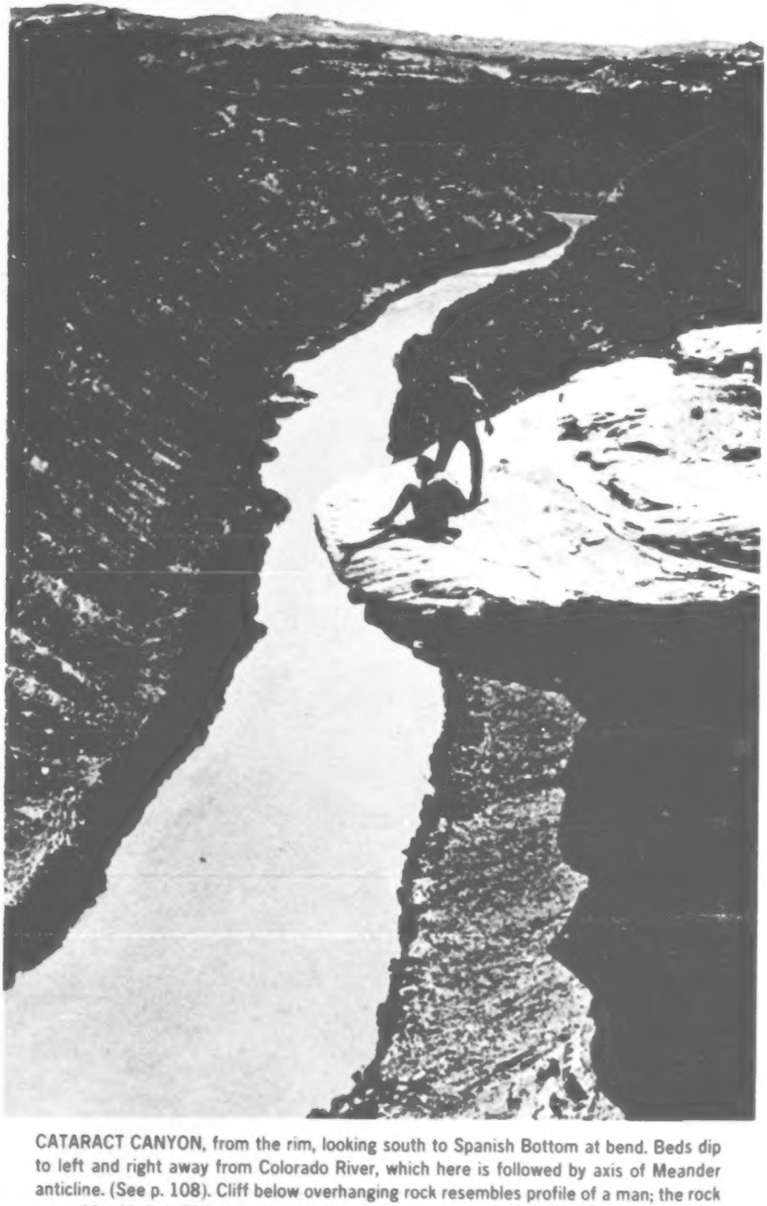
LOWER ELEPHANT CANYON, followed by jeep trail from near Silver Stairs to Elephant Hill. (Fig. 58)



THE CONFLUENCE FROM THE AIR, and some of The Grabens. See also figure 51. Vertical aerial photograph by U.S. Geological Survey. (Fig. 59)



THE CONFLUENCE FROM CONFLUENCE OVERLOOK, shown in figures 1 and 59. Green River entering from left, Colorado River from right. Red beds near top are Rico Formation, overlain by Cedar Mesa Sandstone and underlain by unnamed upper member of Hermosa Formation. (Fig. 60)



CATARACT CANYON, from the rim, looking south to Spanish Bottom at bend. Beds dip to left and right away from Colorado River, which here is followed by axis of Meander anticline. (See p. 108). Cliff below overhanging rock resembles profile of a man; the rock resembles his hat. Photograph by Walter Meayers Edwards, © 1971 National Geographic Society. (Fig. 61)

Canyons of the Green and Colorado Rivers

We have discussed two of the three major topographic divisions of the park—the high mesas and the benchlands—and there remains to consider the third division—the canyons of the mighty Green and Colorado Rivers and some of their tributaries. After we discuss a few features common to both rivers, we will take up the details of each river.

A glance at the map (fig. 1) shows that above the confluence both rivers are very crooked and contain many loops, or meanders, the most striking of which are Bowknot Bend of the Green River (fig. 62), several miles north of the park, and The Loop of the Colorado River (fig. 74). In contrast, the main stem of the Colorado River below the confluence is considerably straighter. Not apparent on the map are the facts that the crooked rivers above the confluence have very gentle grades and are free from rapids or falls, whereas a few miles south of the confluence the main stem plunges into Cataract Canyon—the steepest and wildest reach of the river, containing 64 rapids. These differences are partly explicable on the basis of the geologic structure and character of the rocks through which the rivers have cut. Above the confluence, the soft strata dip gently northward, so in flowing generally southward the two rivers are cutting "against the grain," which tends to impede their flow and thus reduce their grades. Below the confluence, the hard limestones of the Hermosa Formation lie relatively flat for several miles and then begin to dip gently southward, thus allowing the river to cut "with the grain" and therefore drop more rapidly.

The quiet, smooth waters above the confluence permit power boating between the towns of Green River, Utah, and Moab during part of the year, whereas the rapids below Spanish Bottom, 3½ miles below the confluence, restrict river travel to float trips using sturdy boats or rafts.

Above the confluence, a so-called Friendship Cruise is run each year during the Memorial Day weekend. Participants tow their own power boats on trailers to the town of Green River, and after the boats are launched, facilities are available at nominal cost for transporting cars and boat trailers to Moab to await the arrival of the boats. Although some high-powered speedboats are reported to have made the run down the Green River to the confluence then up the Colorado River to Moab in a few hours, the trip for most boats requires 2 to 7 days.

Trips by power boats, including jet boats, can be arranged from either Green River or Moab. Some passengers from Moab return by jeep from Lathrop Canyon via the White Rim Trail, and some from Green River return on land via the Horsethief Trail. Many prefer the quieter float trip down to the confluence, with return to either town by a prescheduled power boat, and some more adventurous souls float through the rapids of Cataract Canyon all the way to Lake Powell.

In the spring of 1972, a 93-foot 150-passenger stern-wheeler (fig. 69) began passenger service on the Colorado River from just above Potash to the foot of Dead Horse Point and return (Lansford, 1972).

Entrenched and cutoff meanders

Meanders such as those above the confluence generally are formed by streams flowing in soft alluvium consisting of clay, silt, and sand, such as along the Mississippi River below Cairo, Ill. But there is no soft alluvium along the Colorado and Green Rivers, so how did these meanders form? They probably attained their serpentine shape while cutting in softer, younger material, which long ago was removed by erosion, and then continued to cut their crooked channels down, until they created the deep rock-walled canyons in which they now flow as "entrenched" meanders.

Meandering streams tend to shorten their lengths from time to time by cutting through narrow walls between adjacent loops, leaving abandoned horseshoe-shaped channels or lakes. In most of the United States these are known as oxbows or cutoff meanders, but in the desert Southwest they are commonly called by the Spanish term "rincon." Cutoffs are common along soft alluvial channels such as the lower Mississippi River valley but are rare along channels whose meanders are entrenched into hard rock. Thus, there have been many natural (and several manmade) cutoffs along the lower Mississippi during historic times, but the most recent ones along the Green and upper

Colorado Rivers probably occurred a million or so years ago, during the Pleistocene Epoch (figs. 65, 80).

Mark Twain served several years as an expert riverboat pilot on the Mississippi River during which several cutoffs took place. Chapter 27 of his "Life on the Mississippi" contains sage references to both natural and artificial cutoffs and concludes with a few good-natured jibes at geologists in particular and scientists in general:

> Therefore the Mississippi between Cairo and New Orleans was twelve hundred and fifteen miles long one hundred and seventy six years ago. It was eleven hundred and eighty after the cutoff of 1722. It was one thousand and forty after the American Bend cut-off. It has lost sixty-seven miles since. Consequently, its length is only nine hundred and seventy-three miles at present.
>
> Now, if I wanted to be one of those ponderous scientific people, and "let on" to prove what had occurred in the remote past by what had occurred in a given time in the recent past, or what will occur in the far future by what has occurred in late years, what an opportunity is here! Geology never had such a chance, nor such exact data to argue from! Nor "development of species," either! Glacial epochs are great things, but they are vague—vague. Please observe:
>
> In the space of one hundred and seventy-six years the Lower Mississippi has shortened itself two hundred and forty two miles. That is an average of a trifle over one mile and a third per year. Therefore, any calm person, who is not blind or idiotic, can see that in the Old Oōlitic Silurian Period, just a million years ago next November, the Lower Mississippi River was upward of one million three hundred thousand miles long, and stuck out over the Gulf of Mexico like a fishing rod. And by the same token any person can see that seven hundred and forty-two years from now the Lower Mississippi will be only a mile and three-quarters long, and Cairo and New Orleans will have joined their streets together, and be plodding comfortably along under a single mayor and a mutual board of alderman. There is something fascinating about science. One gets such wholesale returns of conjecture out of such a trifling investment of fact.

Green River

Much more has been written about the Green River and the main stem of the Colorado than about the Colorado above the confluence (the former Grand River), because all but one of the early float trips began on the Green. The first reports concerning Powell's memorable voyages of 1869 and 1871 were his articles published in Scribners Monthly during 1874 and 1875 followed by his formal 1875 report "Exploration of the Colorado River of the West and Its Tributaries." As pointed out by Porter (1969, p. 21), however, Powell's narrative

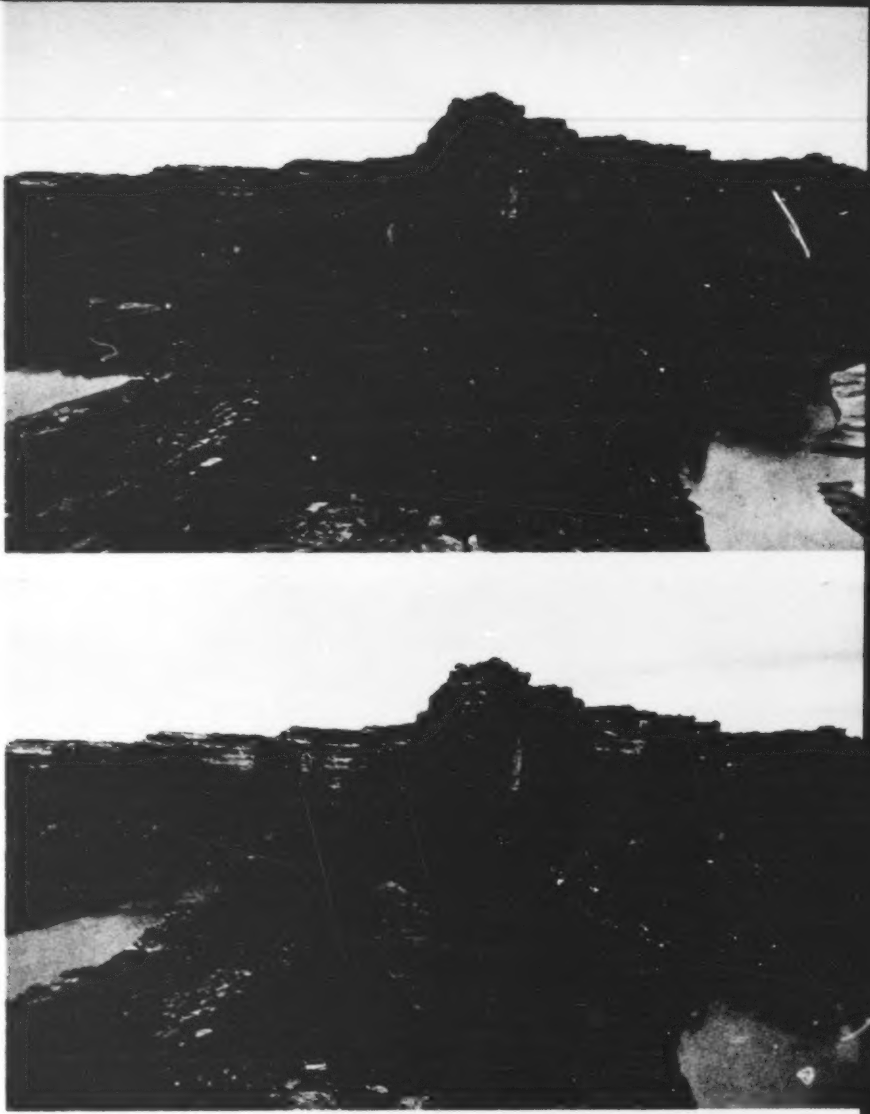
> is written *as if* everything chronicled therein occurred during the first trip. Events which actually occurred in 1871 and 1872 are reported as happening in 1869. There is no mention of the personnel of the 1871-72 party, nor is there an indication that there even *was* a second trip. The engravings illustrating the report were made from photographs taken by Beaman and Hillers between 1871 and 1874, but this fact is not noted.

For these reasons, Porter's account contains Powell's diary of the first (1869) trip and many of the missing photographs, plus his own beautiful color prints. Much more complete and accurate accounts of the 1871 voyage than those of Powell, including many of the photographs taken by Beaman and Hillers, were given by Dellenbaugh (1902, 1962), who was a member of Powell's 1871 expedition.

Numerous river trips were undertaken in the years following Powell's pioneering expeditions. The ill-fated Brown-Stanton voyage of 1889-90 included starts on both the Grand and the Green Rivers. (See section on "Colorado River.") More successful were Nathan Galloway and William Richmond, trappers who left Henrys Fork, Wyo., late in 1896 and reached Needles, Calif., on February 10, 1897 (Kolb, 1927, p. 338). Trappers Charles S. Russell, E. R. Monette, and Bert Loper left Green River, Utah, in three steel boats on September 20, 1907; Russell and Monette reached Needles in one boat in February 1908, but Loper was drowned. Dellenbaugh's 1902 book was carried by the Kolb brothers as a guide for their 1911 trip down the river (Kolb, 1927). In addition to making superb still photographs, the Kolb brothers took the first moving pictures in the canyons, and these are still being shown in the Kolb Studio on the South Rim of the Grand Canyon. Julius F. Stone and party traversed the canyons in 1909, and his account (1932) also contains excellent photographs. E. C. LaRue, of the U.S. Geological Survey, and assistants made two trips down the Green and Colorado Rivers in 1914 and 1915 and additional trips from 1921 through 1924. Their comprehensive hydrographic findings and studies, plus excellent photographs, are given in two reports (La Rue, 1916, 1925). The 1916 report also contains (p. 16-22) a good condensed account of earlier explorations and voyages from 1531 through 1911, taken in part from Dellenbaugh (1902).

As noted earlier, a modern river runners' guide by Mutschler (1969), which logs the Green and Colorado Rivers from Green River, Utah, to Lake Powell, is now available. River mileages in this log were taken from detailed topographic maps of both rivers prepared under the direction of Herron (1917). We will visit only a few notable features of the canyons; the mile-by-mile details for the Green River can be obtained from Mutschler (1969), and those for the Colorado River from Baars and Molenaar (1971, p. 61-99). Several other references are given below, and additional ones are given by Rabbitt (1969, p. 20-21).

All travelers down the Green River embarking from Green River, Utah, or above, were impressed with Bowknot Bend (fig. 62), so named by Powell and his men (1875, p. 54) near the begin-

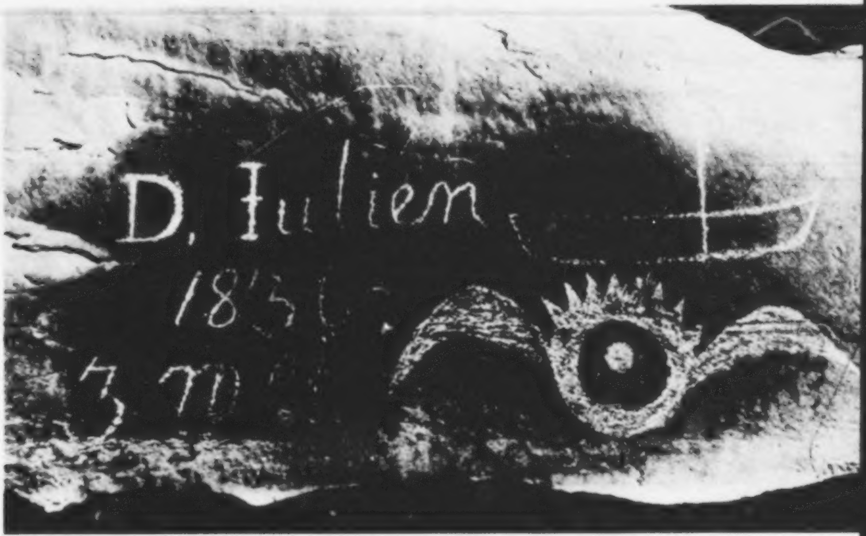


BOWKNOT BEND, of Green River, looking east from west end of narrow intervening saddle. Upper photograph was taken by E. O. Beaman on September 10, 1871, during second voyage of Major John Wesley Powell and his party. Lower photograph was taken from same camera station on August 19, 1968, by Hal G. Stephens, U.S. Geological Survey, on expedition led by E. M. Shoemaker to recover camera stations of the 1871 voyage and rephotograph the scenes to record changes during the nearly 100 year interval. Note that almost no changes occurred in the bedrock, or even in the loose rocks, but that considerable change occurred in the vegetation along the river. Although salt cedar (tamarisk) had been introduced into this country from the Mediterranean area long before 1871, it had not yet spread to this area, but the bare islands shown in the earlier photograph are covered by salt cedar in the 1968 photograph. (Fig. 62) ning of Labyrinth Canyon, which they also named for its deeply entrenched meanders. The upper photograph in figure 62 was taken by Beaman on September 10, 1871, looking eastward from the west end of the narrow saddle separating the upper and lower reaches of the river; the lower photograph was taken from the same point on August 19, 1968, by Hal G. Stephens nearly 97 years later. Although there are changes in the vegetation, as described in the caption, there are virtually no visible changes in the bedrock. Nevertheless, the distant future will likely see a breakthrough, whereby Green River will shorten itself by about 7 miles (Herron, 1917, pl. 15C). It is interesting to note that the vertical cliffs of Wingate Sandstone in and west of Bowknot Bend are only a few hundred feet above the river, whereas, because of the gentle northward dip of the beds and the gentle southward grade of the rivers, the Wingate cliffs are more than 2,000 feet above the two rivers at Grand View Point and Junction Butte, at the southern tip of Island in the Sky.

At the mouth of Horseshoe Canyon, about 3 miles below Bowknot Bend, we pass a large rincon where the Green River shortened its course by about 3 miles. Some idea of the rincon's antiquity is gained from the facts that the river is now some 350 feet lower than at cutoff time, whereas Bowknot Bend (fig. 62) has shown no visible deepening in 97 years. This rincon was not noted by Powell or other early voyagers, seemingly because they did not happen to climb the banks at this point, but it is quite noticeable on modern topographic maps and on aerial photographs. This rincon and Jackson Hole along the Colorado River may be as old as late Tertiary (fig. 80).

At a point reported to be 350 yards above the mouth of Hell Roaring Canyon, which enters from the east about 3½ miles below the rincon, an early day trapper named Julien left his mark. Stone (1932, p. 69, pl. 39A) seems to have been the first river runner to find (from a description given him by a Mr. Wheeler at Green River), record, and photograph the inscription shown in figure 63. Mutschler (1969, p. 31) indicated that this inscription is carved on a massive Moenkopi sandstone bed about 40 feet above the canyon floor. A similar inscription by Julien was found in Cataract Canyon, 31 miles below the confluence, but it is now covered by Lake Powell (Mutschler, 1969, p. 65).

Some boaters are met by car and taken out to Moab or Green River via the Horsethief Trail (fig. 1), just north of the park. The road along the river here continues south for 6½ miles to the mouths of Taylor and Upheaval Canyons, where it becomes the White Rim Trail.



INSCRIPTION BY JULIEN, near mouth of Hell Roaring Canyon, thought to have been carved by Dennis Julien, an early day trapper. Photograph by K. Sawyer, August 1914, member of expedition led by E. C. La Rue (1916). (Fig. 63)

Coming down the Green River, we enter Canyonlands National Park where the Grand-San Juan county line meets the Emery-Wayne county line (fig. 1), about 2¼ miles north of Taylor and Upheaval Canyons. The National Park Service had three successful test wells put down in Taylor Canyon, and water under artesian pressure was found in the White Rim Sandstone at depths of 373 to 482 feet. When funds become available, they hope to complete one or more of these wells and pump the water up to Island in the Sky, where two dry holes were drilled earlier.

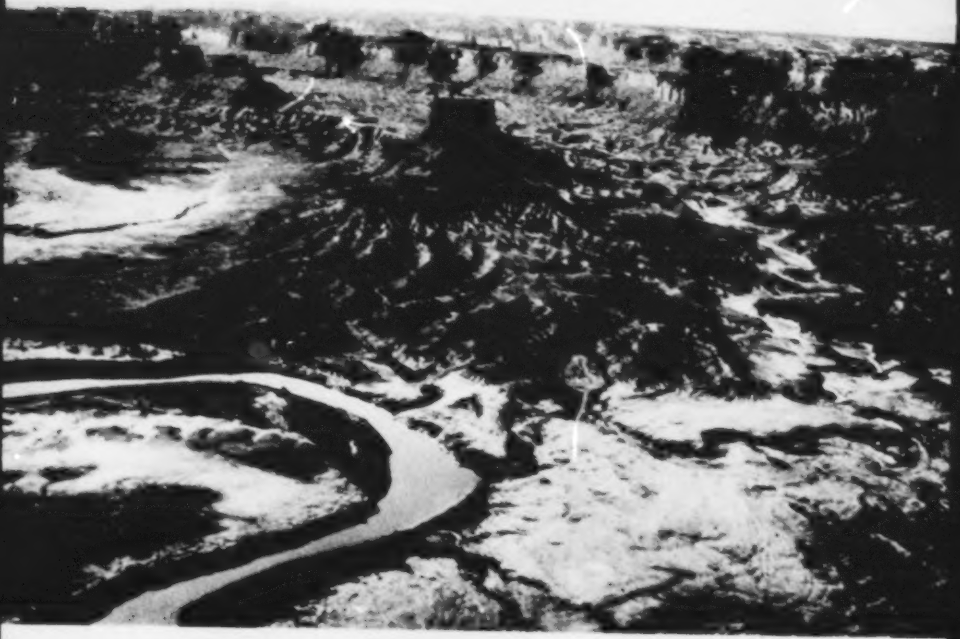
About 5½ miles below Upheaval Canyon is an interesting ruin on a hill in the middle of a large nearly closed loop of the river enclosing Fort Bottom. This was noted by Dellenbaugh (1902) during Powell's 1871 trip and was described in more detail by Mutschler (1969, p. 33-34):

> The ruin consists of two, two-story, interconnected, crudely circular towers, and a third separate, completely collapsed tower, built on the summit of the bluff with a commanding view downriver and of Fort Bottom. Other collapsed structures are present on the summit, and a slab-lined cist is present beneath the Moss Back ledge west of the towers. The ruin was built of dry laid masonry and most of the mud plaster on the inside has been washed away, leaving the structure in danger of imminent collapse. Please do not climb the walls!

Fort Bottom also contains a cabin believed to have been used by Butch Cassidy and the Wild Bunch (Baker, 1971, p. 198).

At about the mouth of Millard Canyon, we leave Labyrinth Canyon and enter Stillwater Canyon, aptly named by members of the 1869 Powell voyage (Dellenbaugh, 1902, p. 276). The beginning of Stillwater Canyon is marked by vertical walls of the White Rim Sandstone. From here Powell's men observed a butte to the southwest thought to resemble a fallen cross and named it "Butte of the Cross." Farther downstream they realized they had been looking at two buttes, a small one in front of a larger one, so the feature was renamed "Buttes of the Cross." An aerial view of Buttes of the Cross is shown in figure 64.

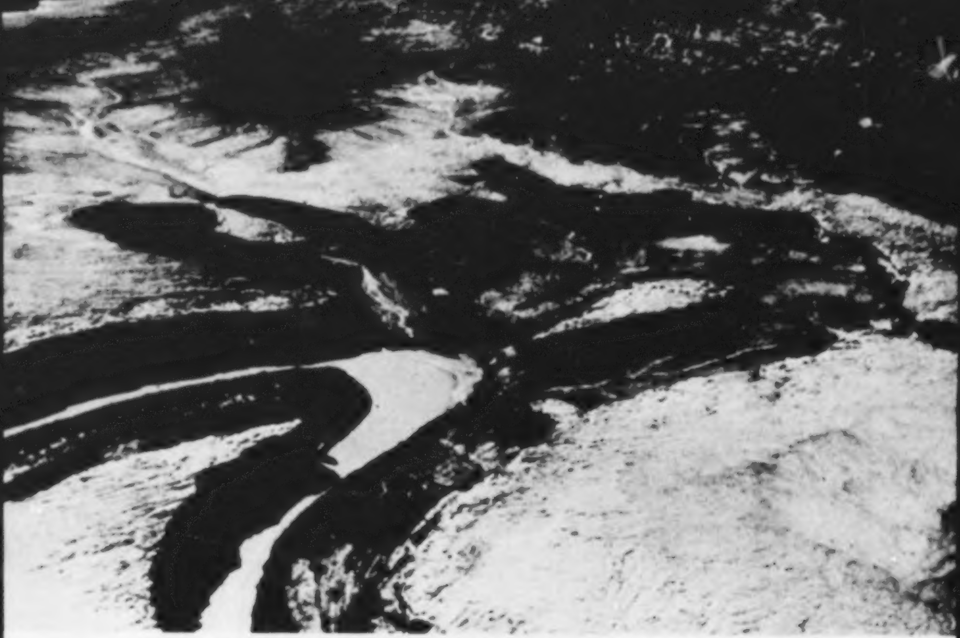
BUTTES OF THE CROSS, looking southwest from the air. Millard Canyon enters Green River in foreground, North Point is in right middle ground, Orange Cliffs are in background, and Henry Mountains form right skyline. White Rim Sandstone forms White Rim near mouth of Millard Canyon and near Anderson Bottom at left middle. (See fig. 65.) Buttes are Wingate Sandstone capped by Kayenta Formation; slopes down to prominent ledge are Chinle Formation, Moss Back Member forming the ledge; steep and gentle slopes between ledge and White Rim are Moenkopi Formation. Photograph by National Park Service. (Fig. 64)



About 2 miles below the mouth of Millard Canyon, at Anderson Bottom, we reach one of the most interesting features on the river—the most recent rincon of a major river in the park, if not in the entire canyon country. Although some rincons are more recent, they are along minor tributaries such as Indian Creek (fig. 73). The cutoff at Anderson Bottom probably took place during the Pleistocene Epoch, whereas most of the others along the main rivers probably occurred during the Tertiary Period (fig. 80). An aerial view of the Anderson Bottom rincon is shown in figure 65, and a sketch of the drainage change is shown in figure 66. This feature was noted and correctly interpreted by Powell and his men, who applied the name Bonita Bend to the sharp new course the river took after the cutoff.

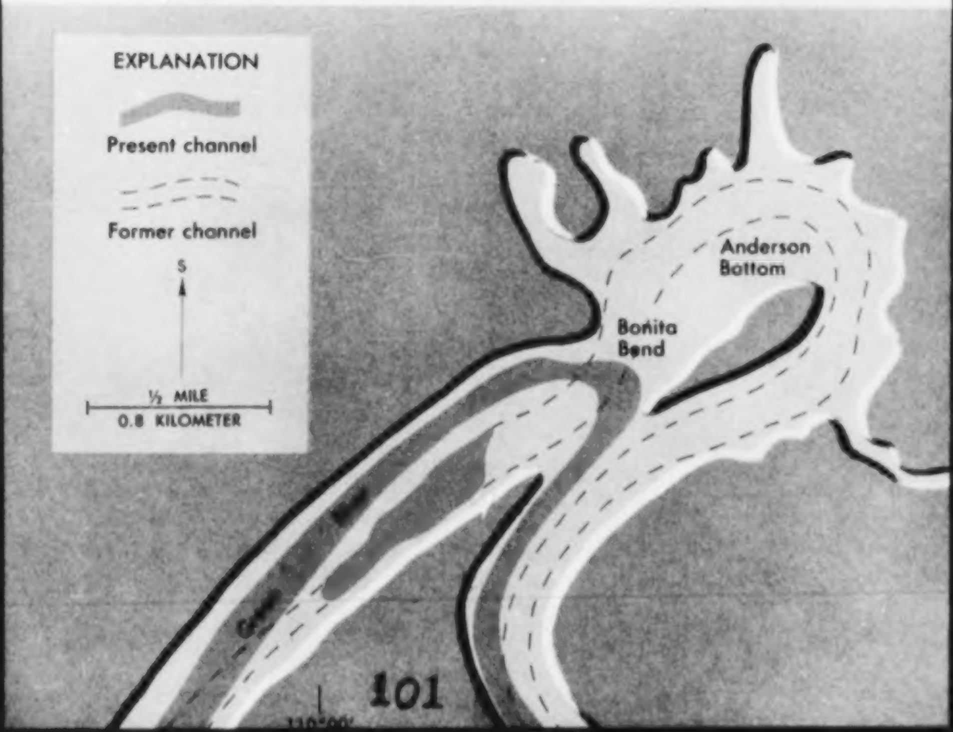
Continuing through Stillwater Canyon, we pass Turks Head (figs. 23, 24) and head for the confluence of the Green River with the Colorado River. Figure 67 shows the canyon just west of the confluence. The lowest and largest cliff above the river is the upper member of the Hermosa Formation, overlain by the slopes and thin ledges of the Rico Formation. The massive sandstone at the top of the canyon wall is the Cedar Mesa. Junction Butte and Grand View Point are on the right skyline.

We have already viewed the confluence and Cataract Canyon from the land and from the air (figs. 59-61); soon we will see them from the Colorado River.

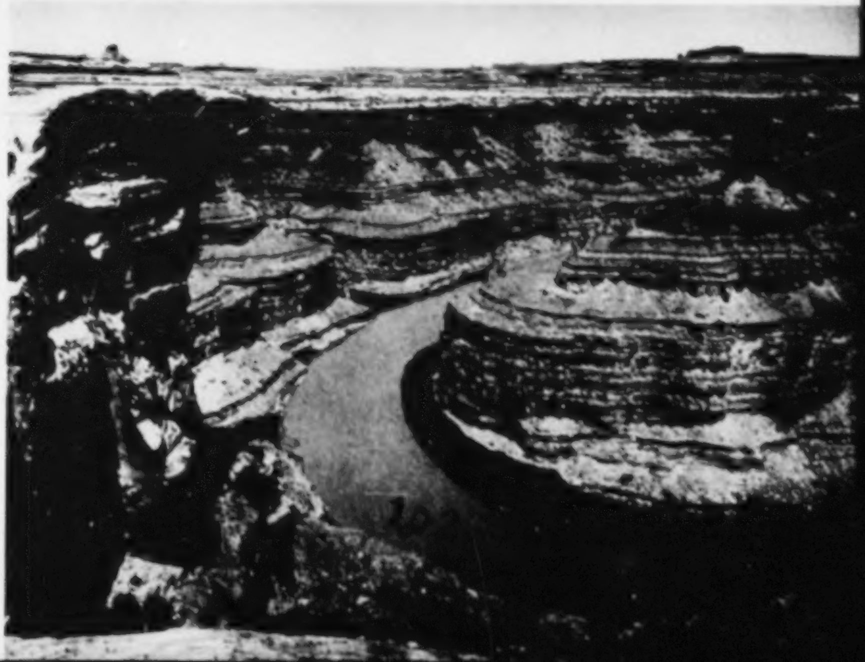


ANDERSON BOTTOM RINCON, aerial view looking southeast. Jointed White Rim Sandstone forms the clifflike canyon walls and the mesa in middle of Anderson Bottom. Green River is now about 60 feet lower than former channel at right. Photograph by National Park Service. (Fig. 65)

DRAINAGE CHANGES AT ANDERSON BOTTOM RINCON. River shortened itself about 2 miles by this cutoff. (Fig. 66)



STILLWATER CANYON, of Green River, viewed from a point on the south rim about 1 mile above (west of) confluence with the Colorado River. Upper photograph was taken by E. O. Beaman on September 16, 1871, during second Powell voyage. Lower photograph was taken from same camera station on August 23, 1968, by Hal G. Stephens, U. S. Geological Survey. (See caption for figure 62.) Note that there are no noticeable changes in rocks or bushes away from the river but that sand bars in the early photograph are covered with salt cedar (tamarisk) in the later photograph, as described for figure 62. (Fig. 67)



Colorado River

As indicated earlier, all but one of the early river voyages began on the Green River. The Grand (Colorado) River above the confluence was neglected for some 18 years after Powell's second voyage, until, in 1889, Frank M. Brown organized a company for construction of the proposed Denver, Colorado Canyon, and Pacific Railway. This railroad was to carry coal from mines in Colorado over a "water-level" line through the canyons of the Colorado River to the Gulf of California some 1,200 miles away; from there the coal would presumably be shipped to ports as far north as San Francisco (Dellenbaugh, 1902, p. 343-369). On March 26, 1889, Brown, president, F. C. Kendrick, chief engineer, and T. P. Rigney, assistant engineer, drove the first stake for a survey of the new line at Grand Junction, Colo., then Brown left for the East to obtain financing, and the other two plus some hired hands took off down the Grand River. After reaching the confluence they towed the boat up the Green River, thus becoming the first to make this trip upstream. They nearly ran out of food, but thanks to the hospitality of some cattlemen, they replenished their stock and after about 9 days reached the railroad at Green River, Utah. Brown, who had returned from the East, his newly appointed chief engineer, Robert Brewster Stanton, and 14 others in six ill-designed boats of cedar, rather than oak, left Green River on May 25, 1889. Against the advice of Major Powell and A. H. Thompson, Powell's topographer on the 1871 trip, they carried no life preservers. After many mishaps, Brown and two others were drowned near the head of Marble Canyon, and the ill-fated expedition was temporarily halted. However, the indefatigable Stanton contracted for new boats built of oak and, with a reorganized party of 12, left the mouth of the Fremont (Dirty Devil) River on November 25. After many further mishaps, the party finally reached the Gulf of California on April 26, 1890. Needless to say the proposed railway was not built.

Although the Colorado River enters Canyonlands National Park about 33 river miles below Moab, most boaters or floaters begin their voyage either at Moab or near Potash, and most travelers of the White Rim Trail begin at Moab, so we will start our trip at Moab. No logs or river runners' guides are available as yet for the reach from Moab to Potash, but below Potash some details of the geology have been described by Baars in Baars and Molenaar (1971, p. 59-87).

As noted at the beginning of this chapter, above the confluence both the Green and Colorado Rivers are very crooked, have very low grades, and are free from rapids. As with the Green, the soft rocks along the Colorado have a generally low northward dip that partly explains the river's gentle grade and its southward flow through increasingly lower and older strata. Unlike the Green, however, the gentle dips of the strata in the canyons of the Colorado are interrupted by several gentle anticlinal (fig. 14) and synclinal (fig. 26) folds and by at least one fault. The most important of these geologic structures and other features will be noted as we journey down the river.

The first 14 miles from Moab Valley to Potash can be made either by river or by paved Utah Highway 279. This highway leaves U.S. Highway 163 near the uranium ore-reduction plant several miles northwest of Moab, leaves Moab Valley through The Portal (fig. 68), and follows the west bank of the river. A paved secondary road from Moab follows the east bank of the river through The Portal and through Kings Bottom, where it crosses the Kings Bottom syncline, to the mouth of Kane Springs Canyon, then becomes a gravel road that ascends this canyon southward to and beyond Hurrah Pass (fig. 30). High above this road north of Kings Bottom are petroglyphs and a few cliff dwellings in the vertical cliffs of Wingate Sandstone. A ranch "house" at Kings Bottom has been excavated entirely into the Wingate cliff. Convenient turnouts have been provided at several places along Highway 279 for viewing petroglyphs or other points of interest. Small viewing tubes welded to vertical steel posts having signs help visitors locate and see the features described.

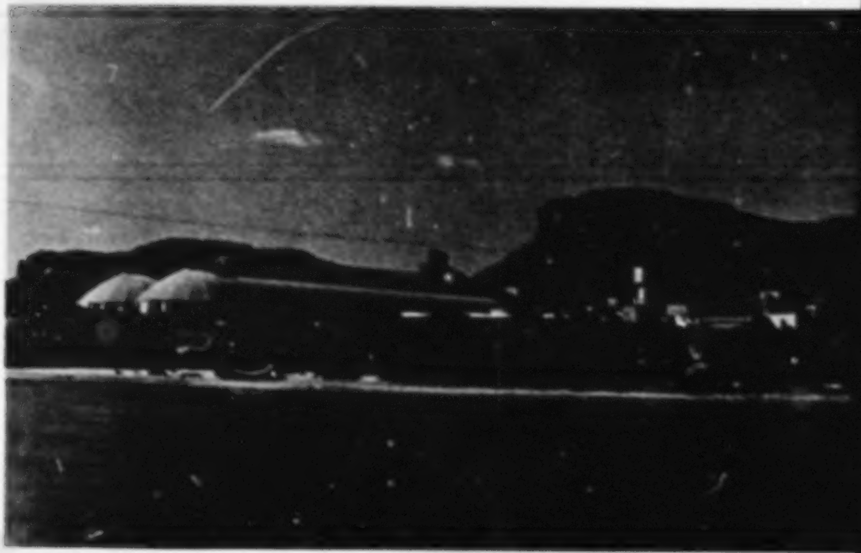
THE PORTAL, in south wall of Moab Valley, through which the Colorado River, Utah Highway 279 (on right), and a paved secondary road (on left) leave the valley to enter the canyons in and above Canyonlands National Park. Rounded remnants on top are Navajo Sandstone; cliffs are Kayenta Formation and Wingate Sandstone; red slopes are Chinle and Moenkopi Formations, and perhaps a little of the Cutler Formation at the base. Light-colored patches at base of slope behind trees on left are contorted intrusions of Paradox Member of Hermosa Formation. (Fig. 68).

The Kings Bottom syncline (fig. 30) southwest of Moab Valley brings the Navajo Sandstone down to and slightly below water level, whereas at The Portal (fig. 68) the Navajo caps the southwest wall of Moab Valley. Several anticlines at or near the river from Potash to and beyond the confluence (fig. 1) bring up strata as old as the Rico or the unnamed upper member of the Hermosa. Between these extremes, much of the river's course lies in strata of the Cutler Formation.

About 7 miles below The Portal, Highway 279 is joined on the right by a branch line of the Denver and Rio Grand Western Railroad completed in 1962 to haul potash 36 miles from the mine at Potash north to the main line at Crescent Junction. The railroad emerges from a tunnel at the head of Bootlegger Canyon. Two natural arches near the mouth of the tunnel—Pinto and Little Rainbow Bridge—can be reached by trail. About 3 miles farther down the Colorado is a temporary dock from which jet boats and the *Canyon King*, a 93-foot 150-passenger stern-wheeler, take off for points downriver during the spring and early summer, when water depth permits. The *Canyon King* (fig. 69), a small replica of a Mississippi River stern-wheeler, carries passengers about 30 miles downriver to the foot of Dead Horse Point and returns (Lansford, 1972).

About 12 miles below The Portal we reach Potash—the potash "mine" (fig. 70) of Texas Gulf, Inc. (See fig. 31 and its associated text for description of operation.) Travelers down the jeep trail below Potash pass the evaporation ponds (fig. 71) used to separate the potash from common salt.

THE *CANYON KING*, a 93-foot 150-passenger stern-wheeler which hauls passengers some 30 miles below Potash and returns. Trips run during the spring and early summer, when water depth permits. Photograph by Henry Lansford, Boulder, Colo. (Fig. 69)



POTASH MINE OF TEXAS GULF, INC. at Potash, as viewed from a boat. High cliffs on right are Wingate Sandstone capped by Kayenta Formation and underlain by slopes of Chinle and Moenkopi Formations. (Fig. 70)

EVAPORATION PONDS, used to separate potash from common salt, viewed from jeep trail. Black borders are parts of plastic membranes covering bottoms of ponds. Crest of Cane Creek anticline and La Sal Mountains in right background. (Fig. 71)

Across the river east from Potash is Jackson Hole, a large rincon. Since abandonment, which shortened the river by about 3½ miles, the river has cut its channel nearly 200 feet deeper. It is comparable in size to the large rincon along Green River below Bowknot Bend (p. 90) but probably is somewhat younger. Both rincons may be as old as late Tertiary (fig. 80). Just below Potash we cross the axis of the huge Cane Creek anticline (fig. 31) and also leave Grand County to enter San Juan County. A mile east of this point, high on the canyon wall, is the School Section 13 uranium mine, which has yielded considerable ore and is expected to resume production sometime during 1973. It can be seen from the river or the trail, and some of the tailings are visible on the left flank of the anticline in figure 13.

Voyagers who cross the axis of the Cane Creek anticline may observe on the right-hand (west) bank a protruding oil-well casing, some drill bits, and several shacks—all that remain of the Frank Shafer No. 1 oil test started during the winter of 1924-25 and completed by the Midwest Exploration Co. (Baker, 1933, p. 81). As described by Maxine Newell (U.S. Natl. Park Service, written commun., 1970),

> The well blew in in December 1925, caught fire, and spewed burning oil 300 feet into the air. * * * The local Times-Independent newspaper called it "Mother Nature's Christmas Gift to Grand County." The gusher burned down the rig, a barge of equipment, and it took three months to get it under control. Then it didn't produce.

Various 1925 and 1926 issues of the Moab Times-Independent reported that despite many efforts to plug the well it continued to flow from 1,000 to several thousand barrels of oil per day for 6 months or more, all of which floated down the river. The last blowout occurred in 1937, after which the well was plugged with an additional 180 tons of cement.

Mrs. Newell added,

> The stories told of the early-day exploration are endless and delightful. Equipment and supplies were barged down the Colorado River by the old Moab Garage Company; in winter months materials were carried by team and sled over the river ice. They would take a couple of rig timbers and pile a lot of lumber on them (they could take 10,000 feet), then we'd give them a start with a crowbar and the mules would trot all the way downhill to the well. When they'd get there they had a little trouble stopping sometimes; they would turn into the bank, unload, then put the double trees on one mule, ride the other, and head back for a new load of rig lumber.

The evaporation ponds shown in figures 31 and 71 are in Shafer Basin, a synclinal basin separating the Cane Creek anticline and Shafer dome. We cross the axis of Shafer Basin about 2 miles below the county line.

Further downstream is Shafer dome, a closed anticlinal bulge just beyond the W-shaped bend in the river as shown in figure 29. Parts of the dome also show up in the lower right of figure 13 and the lower left of figure 15. From almost anywhere in the Goose Neck, the sharp bend of the river shown in figure 15, we get an excellent view of Dead Horse Point some 2,000 feet above.

Robert R. Norman (oral commun. Feb. 27, 1973) described to me a small petrified forest—which he said resembles a log jam—in the eastern part of the Shafer dome, at mileage 39 (Baars and Molenaar, 1971, p. 65), just north of this point about half way between the river and the jeep trail below Dead Horse Point. He estimated that there probably are 20 to 30 logs, some of which are as large as 18 inches in diameter and more than 20 feet long, and also described a stump about 3 feet in diameter. They occur in red beds at about the middle of the Rico Formation, hence could be either Pennsylvanian or Permian in age (figs. 9, 80). The original wood has been replaced by silica (SiO_2) and stained a dark reddish brown, as shown in figure 72.

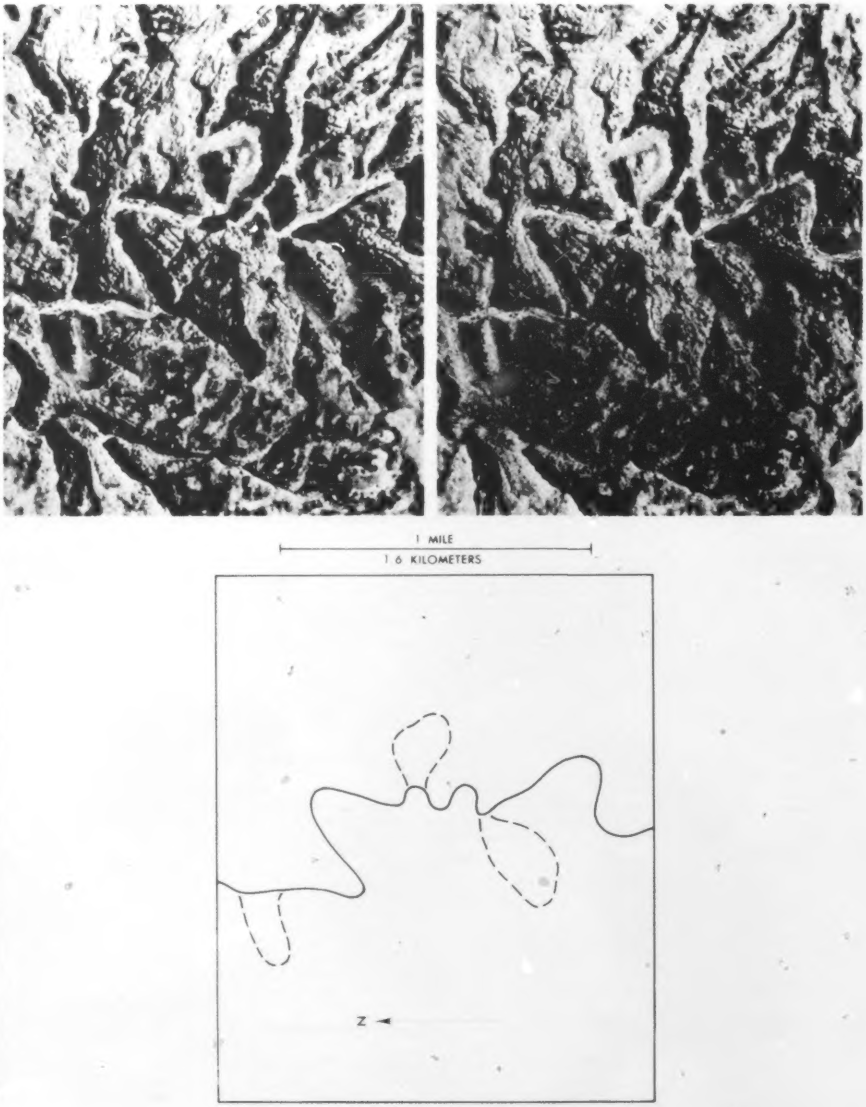
Mr. Norman and his brother also discovered many teeth of a primitive sharklike fish in the Rico Formation at the same general locality as the petrified wood and also in the Rico on the Cane Creek anticline. I submitted two of the teeth to Dr. David H. Dunkle, curator of the Cleveland Museum of Natural History, who reported them to be "one tooth of the cochliodont 'shark' *Deltodus*, and one tooth of the petalodont 'shark' *Petalodus*" (written commun., May 22, 1973).

About 4 miles below the Goose Neck, we enter Canyonlands National Park and remain in the park almost to the north end of Lake Powell.

About 6½ miles into the park, at the north end of a bend much like the Goose Neck, is the mouth of Lathrop Canyon, where many boaters stop for lunch and where a side road connects with the White Rim Trail (fig. 1).

Six and one half miles below Lathrop Canyon is the mouth of Rustler Canyon, which is joined near its mouth by Indian Creek—the creek followed by the highway leading to The Needles from U.S. 163. Within an airline distance of only 3 miles, the lower reach of Indian Creek, an intermittent stream, flows past four small rincons, three of which (fig. 73) are within an airline distance of only 0.8 mile. The stream has cut its new channel into the red sandstones and shales of the Cutler Formation only 15 to 20 feet deeper than the abandoned ones in the two rincons at the left in figure 73 and only about 25 feet deeper than the one on the right. These figures suggest, at least to me, that these cutoffs probably occurred sometime during the Holocene

PETRIFIED LOG, near middle of Rico Formation, about 1 mile southeast of Dead Horse Point. Log is estimated to be about 18 inches in diameter. Photograph by Robert R. Norman. (Fig. 72)

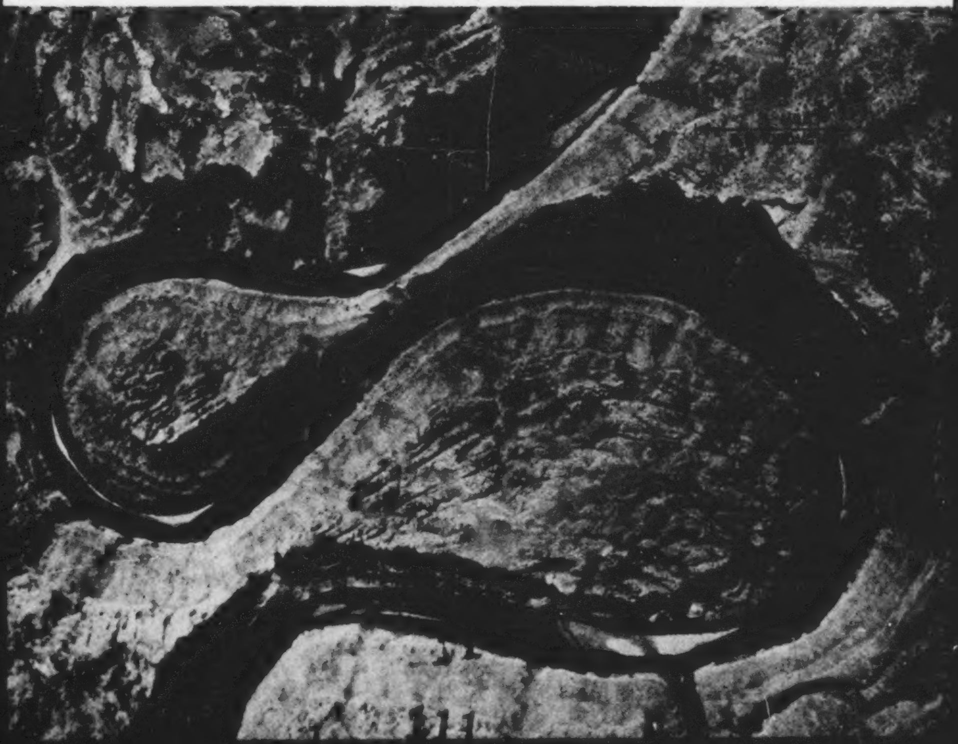


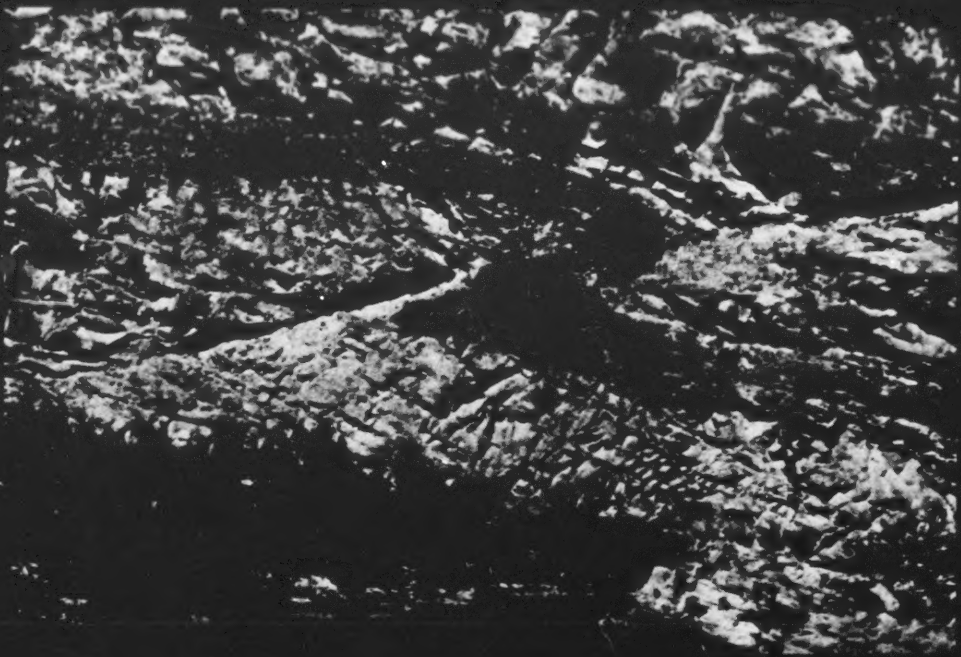
RELATIVELY RECENT RINCONS ALONG INDIAN CREEK, about 3½ miles above mouth and about 2 miles east of Canyonlands National Park. Above, stereoscopic pair of aerial photographs by U.S. Geological Survey; below, sketch showing drainage changes. The stereoscopic pair can be viewed without optical aids by those accustomed to this procedure, or by use of a simple double-lens stereoscope. (Fig. 73)

Epoch, or age of man—that is, probably within the last 10,000 years (fig. 80). A detailed study of these rincons might change this estimate, particularly if, say, buried driftwood or other carbonaceous material could be found for an age determination by the radiocarbon method.

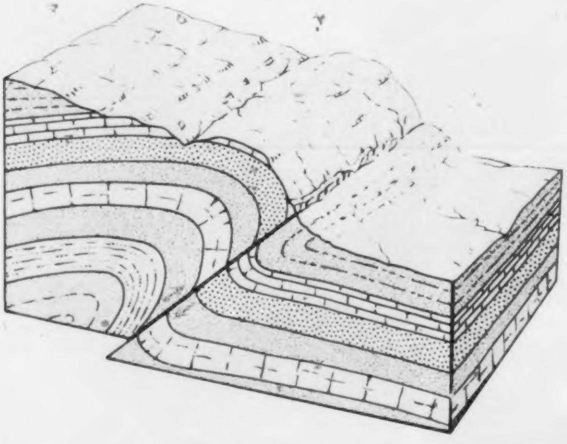
About 5 miles below the mouth of Rustler Canyon and Indian Creek, and also about 5 miles above the confluence, is The Loop—an even sharper and more symmetrical figure eight than Bowknot Bend of the Green River (fig. 62). An aerial view of The Loop (fig. 74) shows that the channels on the south loop are only about 500 feet apart and that those on the north loop are only about 1,700 feet apart. At the narrowest places, both saddles are considerably eroded—the southern one is only about 150 feet above the river, but the northern one is still about 350 feet above. Erosion of both saddles has been hastened by the facts that the axis of the Meander anticline (see p. 108) passes through each saddle and that an interesting reverse fault (fig. 75) passes through the lower and thinner southern saddle. The differences between reverse and normal faults are shown by comparing figures 56 and 76. It seems inevitable that some day the small

THE LOOP, of Colorado River, about 5 miles northeast of the confluence. Lower canyon walls are unnamed upper member of Hermosa Formation overlain by slopes of the Rico Formation. Jointed sandy ledges at top become sandier to south, where they comprise the Cedar Mesa Sandstone. Aerial photograph by U.S. Geological Survey. (Fig. 74)





REVERSE FAULT in southern saddle of The Loop, looking northwest from boat in river. Apparent angle of dip is 12° below horizontal. Rocks at left, above fault plane, have been shoved about 10 feet past and over those on right. Curving of dark bed near middle of fault plane is called "drag." (See fig. 76.) Rocks are unnamed upper member of Hermosa Formation. (Fig. 75)



CUTAWAY VIEW OF REVERSE FAULT, resulting from horizontal compression, which caused a shortening of earth's crust. Note "drag" of beds on each side of fault plane. Low-angle reverse faults, also called thrust faults, may have displacements ranging from a few feet to many miles. From Hansen (1969, p. 116). (Fig. 76) saddle will be cut through by the Colorado River, and a new rincon will result. Eventually, the other loop also probably will be abandoned. As one of my colleagues remarked, how wonderful it would seem, to be present at the proper moment to witness such an event, particularly if one had a time-lapse movie camera to record it for posterity!

About a mile and a half below the south saddle of The Loop we meet the mouth of Salt Creek, which drains a large part of the Needles district. Figure 77 was taken in Salt Creek canyon about 2 airline miles above the mouth looking southeast toward Six-Shooter Peaks and Shay Mountain, northernmost of the Abajo Mountains, on the horizon.

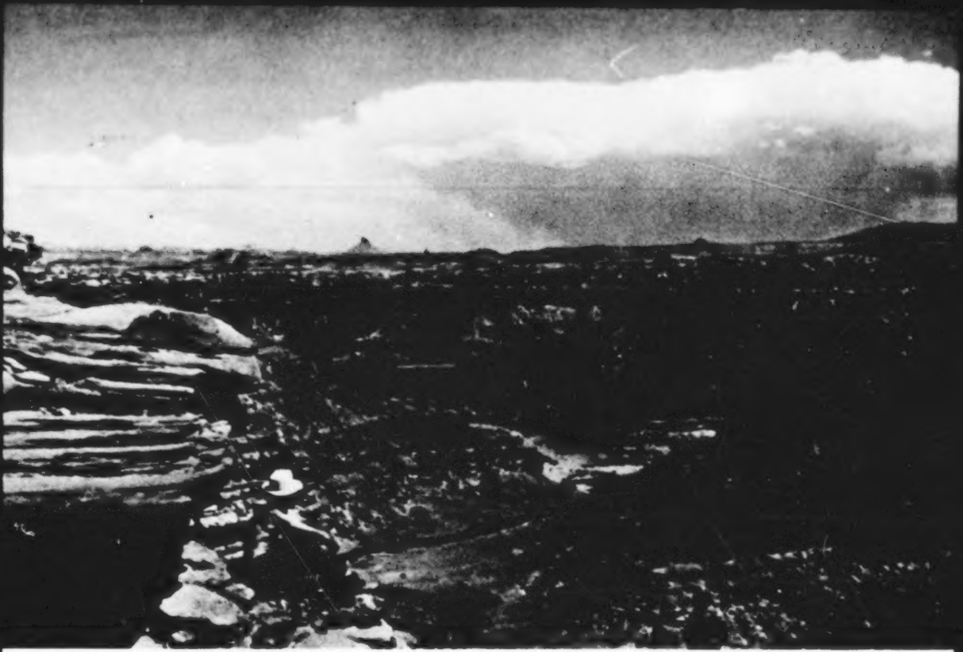
A mile and a half above the confluence is The Slide, a jumbled mass of angular blocks of rock that fell from the northwest canyon wall and originally probably extended all the way to the southeast bank of the river. As shown in figure 78, it still extends nearly across the river, leaving only a narrow deep chute along the southeast bank. Just after the photograph was taken, we hit rough fast water in the chute, with waves about 2 feet high. At higher stages of the river, progressively more of The Slide is covered by water, and there is less tendency for waves to form. The date of this landslide is not known, but it is shown on a map by Herron (1917, pl. 22A) made prior to 1917 and may well have occurred during prehistoric times.

Soon we reach the confluence of the Green and Colorado Rivers (figs. 59, 60). This important junction of two mighty rivers was noted by all previous voyagers, but their impressions of it differed considerably. Powell (1875, p. 56) remarked:

> These streams unite in solemn depths, more than one thousand two hundred feet below the general surface of the country. The walls of the lower end of Stillwater Cañon are very beautifully curved [see fig. 67], as the river sweeps in its meandering course. The lower end of the cañon through which the Grand comes down, is also regular, but much more direct, and we look up this stream, and out into the country beyond, and obtain glimpses of snow clad peaks, the summits of a group of mountains known as the Sierra La Sal [La Sal Mountains]. Down the Colorado, the cañon walls are much broken.

Dellenbaugh (1902, p. 277) gave a fuller description but concluded: "In every way the Junction is a desolate place"—an appraisal with which I disagree. The most colorful account I have read is that of Captain Francis Marion Bishop, a member of Powell's 1871 expedition, who recorded in his journal for September 15, 1871 (1947, p. 202):

> Well, we are at last, after many days of toil and labor, here at the confluence of the two great arteries of this great mountain desert. No more shall our frail boats dash through thy turbid waters, Old Green, and no more shall we press on to see the dark flood from the peaks and parks of Colorado. Grand and Green



SALT CREEK CANYON, looking southeast from point on rim 2 miles above mouth. Lower ledges are limestones in unnamed upper member of Hermosa Formation; slope and upper cliff are Rico Formation capped by remnants of Cedar Mesa Sandstone. Horizon shows Six-Shooter Peaks in center and Shay Mountain, northernmost of Abajo Mountains, at right. Photograph by E. N. Hinrichs. (Fig. 77)

THE SLIDE, which partly blocks the Colorado River about 1½ miles above the confluence. View downstream. (Fig. 78).

> here sink to thy rest, and from thy grave the *Colorado de Grande* shall flow on forever, and on thy bosom henceforth will we battle with rock and wave. One can hardly tell which is the largest of the two rivers. Neither seems to flow into the other, but there seems to be a blending of both, and from their union rolls the Colorado River.

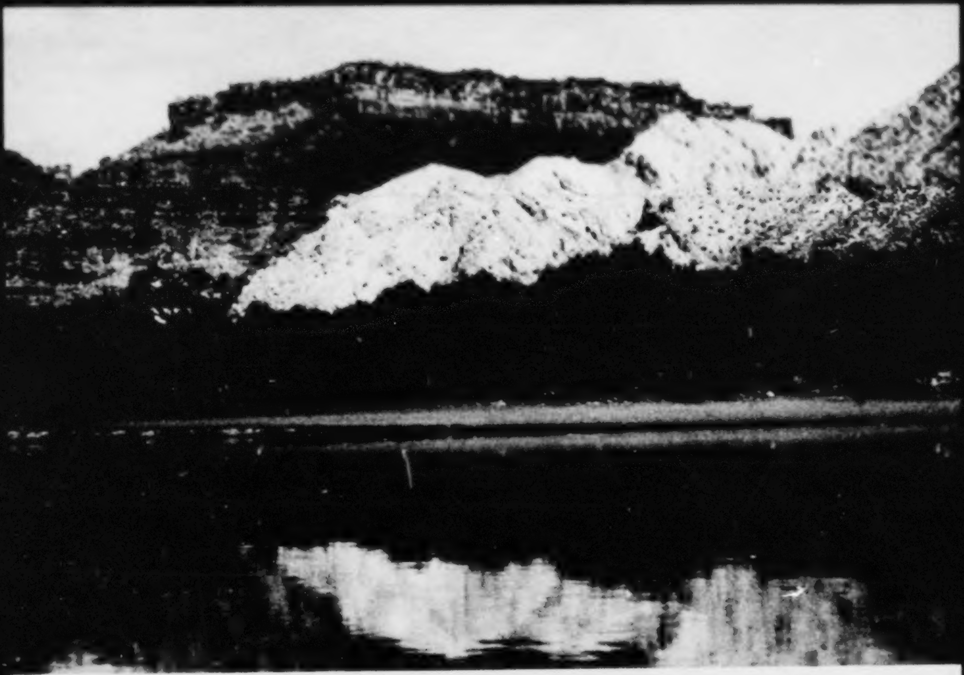
Cataract Canyon heads at the confluence, but the rapids do not appear until we leave Spanish Bottom some 3½ miles below. Between The Loop and Spanish Bottom, the Colorado River follows closely the axis of an anticline. Along this reach the rock strata dip downward away from the river, as shown in figure 61. This fold was noted by Powell and some of his men, and Bishop (1947, p. 203) reported in his journal for September 16, 1871:

> He [Steward] is at a loss how to account for the folded appearance of the strata here. But doubtless will find some explanation. Says the dip recedes from the river cañon, and thinks it is a fissure. Maj. [Powell] thinks it is owing to an upheaval, and that the beds next to the river have broken up from the mass, etc., etc.

Forty-four years later Harrison (1927) named this structure the Meander anticline and concluded that the weight of the rocks on each side of the river had squeezed underlying beds of salt in the Paradox Member of the Hermosa Formation and caused them to move upward along the river, where the confining strata had been removed by erosion. Harrison's theory was accepted by Baker (1933) and most later workers in the area. Thus we have what may be termed an erosional anticline, whose axis, or crest, follows the river. Erosional anticlines also occur elsewhere, as along the Eagle and Roaring Fork valleys of central Colorado. Mutschler and Hite (1969) suggested that this zone of weakness in Canyonlands overlies and follows a break in the hard Precambrian (fig. 80) rocks that underlie the area at great depth. At any rate, Powell was on the right track even though he was totally unaware of the underlying salt or the deep-seated fault.

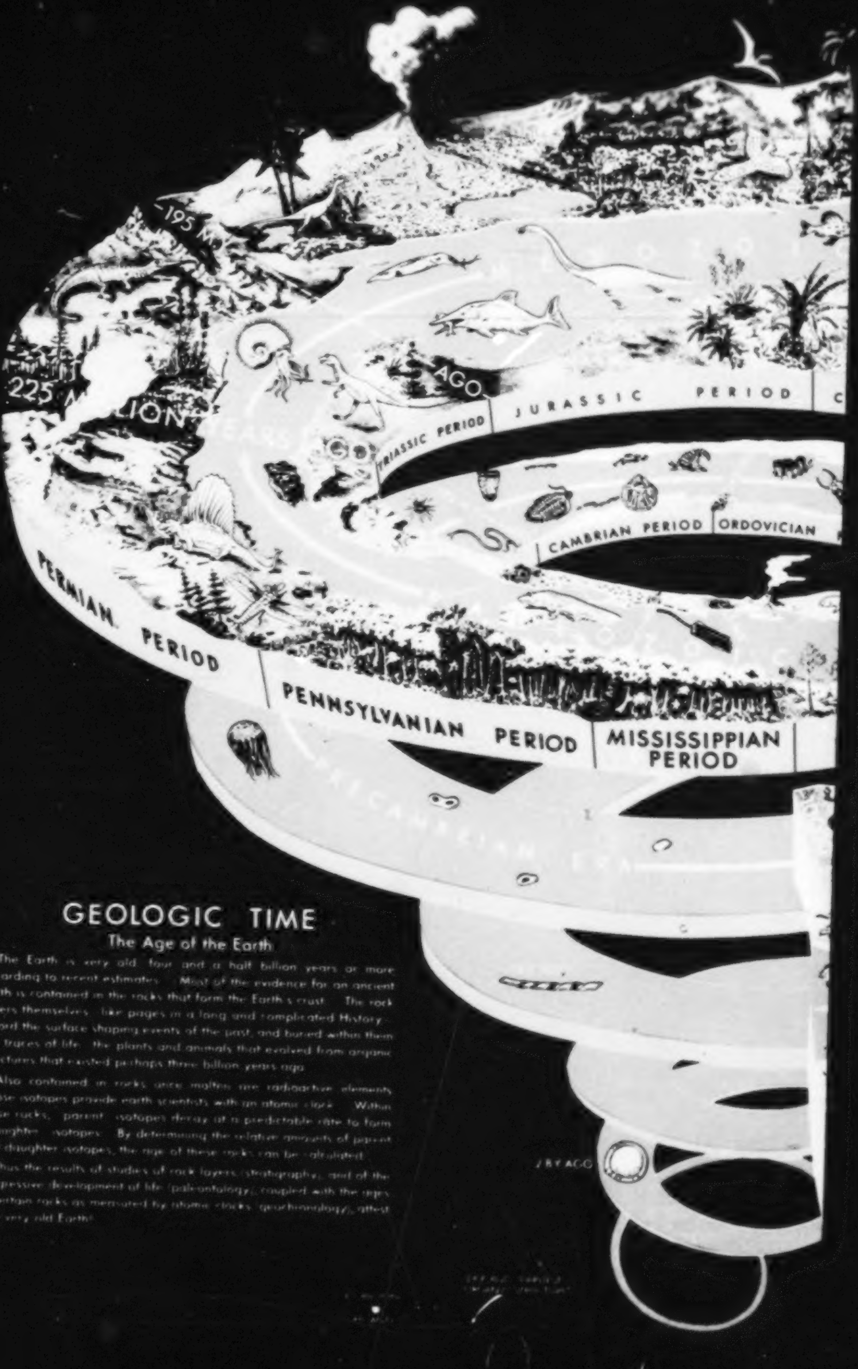
Smooth water continues from the confluence to Spanish Bottom, where the Old Spanish Trail comes down to the river from the west and continues up Lower Red Lake Canyon to the east. As mentioned earlier, this is about the south end of the Meander anticline, and an intruded chunk of the Paradox Member, mostly gypsum, occupies part of the mouth of Lower Red Lake Canyon, as shown in figure 79.

The remaining 10 miles or so of Cataract Canyon within Canyonlands National Park contains many rapids and should be traversed only under the leadership of experienced river guides. If and when Lake Powell reaches its maximum level, it will extend to within about a mile of the park, but at present (1973) it heads near the mouth of Gypsum Canyon, about 5 miles below the park.



GYPSUM PLUG of Paradox Member, intruded along south end of Meander anticline at mouth of Lower Red Lake Canyon. Common salt has been removed by solution, leaving residue of gypsum and some shale. Photograph by Donald L. Baars. (Fig. 79)

GEOLOGIC TIME SPIRAL, showing the sequence, names, and ages of the geologic eras, ▷ periods, and epochs, and the evolution of plant and animal life on land and in the sea. The primitive animals that evolved in the sea during the vast Precambrian Era left few traces in the rocks because they had not developed hard parts such as shells, but hard shells or skeletal parts became abundant during and after the Paleozoic Era. (Fig. 80)



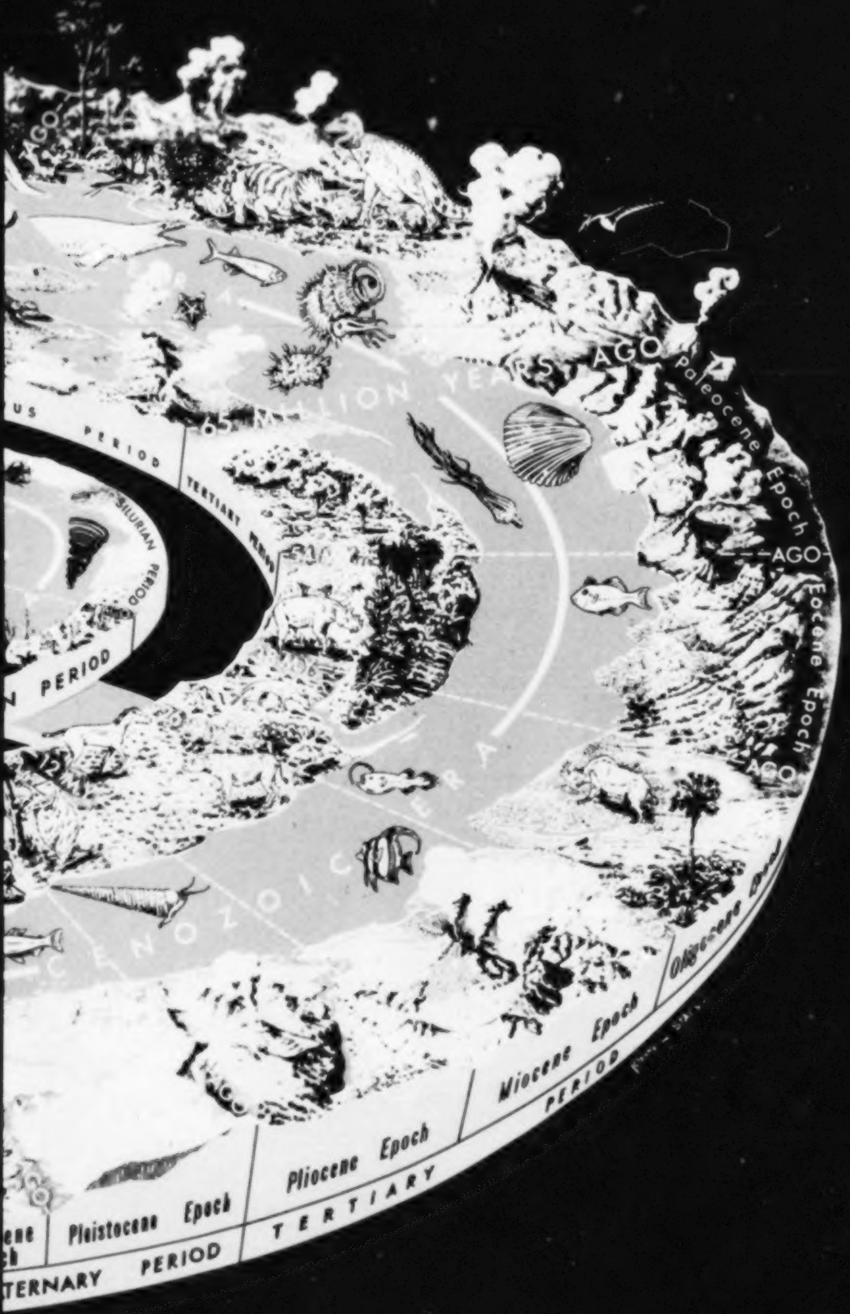
GEOLOGIC TIME

The Age of the Earth

The Earth is very old, four and a half billion years or more according to recent estimates. Most of the evidence for an ancient Earth is contained in the rocks that form the Earth's crust. The rock layers themselves, like pages in a long and complicated History, record the surface shaping events of the past, and buried within them are traces of life, the plants and animals that evolved from organic structures that existed perhaps three billion years ago.

Also contained in rocks, once molten, are radioactive elements whose isotopes provide earth scientists with an atomic clock. Within these rocks, "parent" isotopes decay at a predictable rate to form "daughter" isotopes. By determining the relative amounts of parent and daughter isotopes, the age of these rocks can be calculated.

Thus the results of studies of rock layers (stratigraphy), and of the progressive development of life (paleontology), coupled with the ages of certain rocks as measured by atomic clocks (geochronology), attest to a very old Earth!


AGO
MILLION YEARS AGO
Paleocene Epoch
AGO
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PERIOD
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TERNARY PERIOD
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TERTIARY PERIOD
SILURIAN PERIOD
N PERIOD
12

Summary of Geologic History

Having finished our geologic ramble through canyonlands National Park, let us see how this pile of eroded rocks fit into the bigger scheme of things—the geologic age and events of the earth as a whole, as depicted in figure 80. As shown in figure 9, the rock strata still preserved in the park range in age from Pennsylvanian to Jurassic, or from about 300 to 175 million years ago, a span of about 125 million years. This seems an incredibly long time, until you note that the earth is some 4.5 billion years old and that our rock pile is but one twenty-fifth, or 4 percent, of the age of the earth as a whole. Thus, in figure 80 the rocks exposed in the park occupy only about the left-hand third of the top whorl of the spiral.

But this is not the whole story. As indicated earlier, about 10,000 feet of younger Mesozoic and Tertiary rocks that once covered the area have been carried away by erosion, and if we include these, the span is increased to about 250 million years, or nearly a full whorl of the spiral.

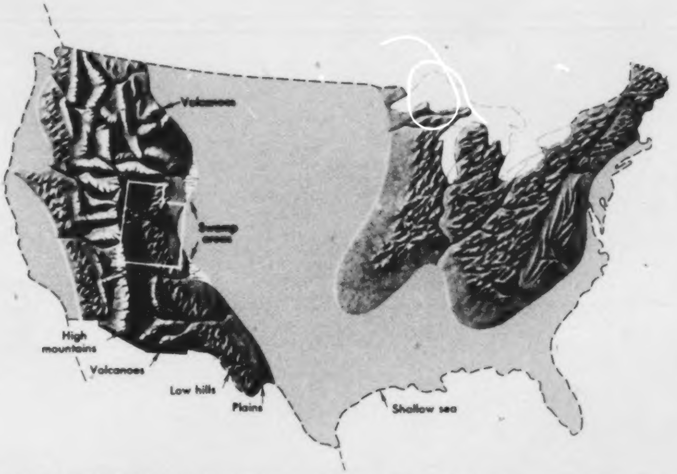
Deep tests for oil and gas tell us that much older rocks underlie the area, and we have seen that some of these rocks played a part in shaping the park we see today—note the breaks in the deep-seated Precambrian rocks and the salt in the Paradox Member. In addition to the Precambrian igneous and metamorphic rocks, there are about 2,000 feet of Paleozoic sedimentary rocks older than the Pennsylvanian Paradox Member. Most of these sedimentary rocks were laid down in ancient seas during Cambrian, Ordovician, Devonian, Mississippian, and Pennsylvanian times (fig. 80). There are some gaps in the rock record caused by temporary emergence of the land above sea level and erosion of the land surface before the land again subsided below sea level so that deposition could resume. Silurian rocks are absent altogether, presumably because here the Silurian Period was dominated by erosion rather than deposition.

While Pennsylvanian and Permian sediments were being deposited in and southwest of the park, a large area to the northeast—called by geologists the Uncompahgre highland, because it occupied the same general area as the present Uncompahgre Plateau—rose slowly above sea level. Whatever Paleozoic rocks there were on this rising land, plus part of the underlying Precambrian rocks, were eroded and carried by streams into deep basins to the northeast and southwest. Thus, while mostly marine or nearshore deposits were being laid down in and near the park, thousands of feet of red beds were being laid down by streams in an area between the park and the Uncompahgre Plateau. During part of Middle Pennsylvanian time a large area including the park and known as the Paradox Basin was alternately connected to or cut off from the sea, so the water evaporated during cutoff periods and was replenished during periods when connection with the sea resumed. In this huge evaporation basin were deposited the layers of salt and gypsum plus some potash salts and shale that now make up the Paradox Member.

The old Uncompahgre highland continued to shed debris into the bordering basins until Triassic time, when it began to acquire a veneer of red sandstone and siltstone of the Chinle Formation (Lohman, 1965). The area remained above sea level during the Triassic Period and most if not all the Jurassic Period, although the Jurassic Carmel Formation was laid down in a sea that lay just to the west.

Late in the Cretaceous Period a large part of central and southeastern United States, including the eastern half of Utah, sank beneath the sea, as shown in figure 81, and received thousands of feet of mud, silt, and some sand that later compacted into the Mancos Shale. This formation and all the younger and some older strata have long since been eroded from the park area but are present in adjacent areas, such as the lower slopes of the Book Cliffs north of Green River, Crescent Junction, and Cisco (fig. 7).

The land rose above the sea at about the close of the Cretaceous and has remained above ever since, although inland basins and lakes received sediment during parts of the Tertiary Period. Compressive forces in the earth's crust produced some gentle folding of the strata at the close of the Cretaceous, but more pronounced folding and some faulting occurred during the Eocene Epoch, when most of the Rocky Mountains took form. During the Miocene Epoch molten igneous rock welled up into the strata to form the cores of the nearby La Sal, Abajo, and



LATE CRETACEOUS SEA, which covered parts of central and southeastern United States. (Fig. 81)

Henry Mountains (fig. 7). Additional uplift and some folding occurred in the Pliocene and Pleistocene Epochs.

Much of the course of the Colorado River was established in the Miocene Epoch, with some additional adjustments in the late Pliocene and early Pleistocene Epochs (Hunt, 1969, p. 67). Erosion during much of the Tertiary Period and all of the Quaternary Period, combined with some sagging and breaking of the crust brought on by solution and lateral squeezing of salt beds beneath The Needles, The Grabens, and the Meander anticline, produced the landscape as we now see it.

The Precambrian rocks beneath the area are about 1.5 billion years old, so an enormous span of time is represented by the rocks and events in and beneath Canyonlands National Park.

If we consider the geologic formations that make up the Colorado Plateau—including national parks (N.P.), national monuments (N.M.) (excluding small historical or archeological ones), Monument Valley, San Rafael Swell, and Glen Canyon National Recreation Area—certain formations or groups of formations play starring roles in some parks or monuments, some play supporting roles, and in a few places the entire cast of rocks gets about equal billing. Let us compare them and see how and where they fit into the geologic time spiral (fig. 80).

Dinosaur N. M., with exposed rocks ranging in age from Precambrian to Cretaceous, represents the greatest time span (nearly 2 billion years) but has one unit—the Jurassic Morrison Formation—in the starring role, for this unit contains the many dinosaur fossils that give the monument its name and fame; several older units have supporting roles. Grand Canyon N. P. and N. M. are next, with rocks from Precambrian through Permian (excluding the Quaternary lava flows in the N. M.), but here there is truly a team effort, for the entire cast gets about equal billing. Canyonlands N. P. stands third in size of cast, with rocks ranging from Pennsylvanian to Jurassic, but we would have to give top billing to the Permian Cedar Mesa Sandstone Member of the Cutler Formation, from which The Needles, The Grabens, and most of the arches were sculptured; the Triassic Wingate Sandstone and Kayenta Formation get second billing for their roles in forming and preserving Island in the Sky and other high mesas.

Now let us consider those with only one or few players in the cast, beginning at the bottom of the time spiral. Black Canyon of the Gunnison N. M., cut entirely in rocks of early Precambrian age (except for only a veneer of much younger rocks), obviously has but one star in its cast. Colorado N. M. contains rocks ranging from Precambrian to Cretaceous—equal to Dinosaur in this respect—but it is unique in that all the rocks of the long Paleozoic Era and some others are missing from the cast; of those that remain, the Triassic Wingate and Kayenta are the stars, with strong support from the Jurassic Entrada Sandstone.

All the bridges in Natural Bridges N. M. were carved from the Permian Cedar Mesa Sandstone, also the star in Canyonlands N. P. In Canyon de Chelly (pronounced "dee shay") N. M. and Monument Valley (neither N. P. nor N. M., as it is owned and administered by the Navajo Tribe), the de Chelly Sandstone Member of the Cutler Formation—a Permian member younger than the Cedar Mesa—plays the starring role.

Wupatki N. M., near Flagstaff, Ariz., stars the Triassic Moenkopi Formation. Petrified Forest N. P. (which now includes part of the Painted Desert) also has but one star—the Triassic Chinle Formation, with its many petrified logs and stumps of ancient trees. The Triassic-Jurassic Glen Canyon Group (fig. 9), which includes the Triassic Wingate Sandstone and Kayenta Formation and the Triassic-Jurassic Navajo Sandstone, receives top billing in recently enlarged Capitol Reef N. P., but the Triassic Moenkopi and Chinle Formations enjoy supporting roles.

The Triassic-Jurassic Navajo Sandstone, erosional remnants of which are found on the high mesas of Canyonlands N. P., is the undisputed star of Zion N. P., Rainbow Bridge N. M., and Glen Canyon National Recreation Area, despite the fact that the latter is the type locality of the entire Glen Canyon Group (fig.

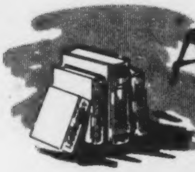
9). The Navajo also forms the impressive reef at the eastern edge of the beautiful San Rafael Swell (a dome, or closed anticline, fig. 7), now crossed by Highway I-70 between Green River and Fremont Junction, Utah.

As we journey upward in the time spiral (fig. 80), we come to the Jurassic Entrada Sandstone, which stars in Arches N. P., with help from the underlying Navajo Sandstone and a supporting cast of both older and younger rocks. The Entrada also forms the grotesque erosional forms called "hoodoos and goblins" in Goblin Valley State Park, north of Hanksville, Utah.

Moving ever upward in the spiral, we come to the Cretaceous—the age of the starring Mesaverde Group, whose caves in Mesa Verde N. P. now house beautifully preserved ruins once occupied by the Anasazi, the same ancient people who once dwelt in Canyonlands N. P.

This brings us up to the Tertiary Period, during the early part of which the pink limestones and shales of the Paleocene and Eocene Wasatch Formation were laid down in inland basins. Beautifully sculptured cliffs, pinnacles, and caves of the Wasatch star in Bryce Canyon N. P. and nearby Cedar Breaks N. M. This concludes our climb up the time spiral, except for Quaternary volcanoes and some older volcanic features at Sunset Crater N. M., near Flagstaff, Ariz.

Thus, one way or another, many geologic units that formed during the last couple of billion years have performed on the stage of the Colorado Plateau and, hamlike, still lurk in the wings eagerly awaiting your applause to recall them to the footlights. Don't let them down—visit and enjoy the national parks and monuments of the Plateau, for they probably are the greatest collection of scenic wonderlands in the world.



Additional Reading

Many reports covering various aspects of the area have been cited in the text by author and year, and these plus a few additional ones are listed below under "Selected References." A few of general or special interest should be mentioned, however.

Between 1926 and 1931 virtually the entire area now included in the park was mapped geologically in three classic reports—two by Baker (1933, 1946) and one by McKnight (1940). These men and their field assistants mapped the area by use of the plane table and telescopic alidade without benefit of modern topographic maps or aerial photographs, except for topographic maps of narrow stretches along the Green and Colorado Rivers made under the direction of Herron (1917). Only small sections could be reached by automobile, so nearly all the area was traversed using horses or by hiking.

During the uranium boom of the early and middle 1950's, the U.S. Geological Survey remapped the topography of most of the area at a scale of 1:24,000 and also remapped the geology of much of the area at this same scale. The southern part of the Needles district was mapped by Lewis and Campbell (1965). The geologic mapping west of the Green and Colorado Rivers was done by F. A. McKeown, P. P. Orkild, C. C. Hawley, and others; that east of the Colorado River and a little between the two rivers was done by E. N. Hinrichs and others. Only four of the geologic maps have been published (Hinrichs and others, 1967, 1968, 1971a, b), but all this work and the older reports were used by Williams (1964) in compiling the 1:250,000-scale geologic map of the Moab quadrangle, by Williams and Hackman (1971) in compiling a similar map of the Salina quadrangle, and by Haynes, Vogel, and Wyant (1972) in compiling a similar map of the Cortez quadrangle. These three maps show the geology of the entire park.

The 1970 issue of the Naturalist in which the cited papers by Jennings, Newell, and Stokes appear also contains other papers on Canyonlands National Park, including one on the plants.

Several early reports on the Green and Colorado Rivers and their potential utilization contain a wealth of information and many fine photographs—two reports on the Colorado River by La Rue (1916, 1925), one on the Green River by Wooley (1930), and one on the upper Colorado River (above the confluence) by Follansbee (1929).

For those who wish to learn more about the science of geology, I suggest the textbook by Gilluly, Waters, and Woodford (1968).

Acknowledgments

My deep appreciation goes to Bates Wilson, former superintendent of Canyonlands National Park, and to Joe Carithers, former assistant superintendent, for their splendid cooperation in supplying data and information and for making available four-wheel-drive vehicles. I also wish to thank Chuck Budge, former chief ranger; Dave May, assistant chief ranger; Joe Miller, former maintenance engineer; Bob Kerr, new superintendent; Maxine Newell, park historian and member of the staff at Arches National Park; Jerry Banta, park ranger at Arches; and Dave Minor, district ranger for the Needles district, for their many favors.

I am grateful to several colleagues and friends for the loan of photographs, for geologic help and data, and for reviewing this report. I am also deeply grateful to my wife Ruth for accompanying me on all the field work and for her help and encouragement.

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